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Ecological Types of the Eastern Slope of the Wind River Range, Shoshone National Forest, Wyoming

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Abstract

This guide presents a classification of the Ecological Types of the eastern slope of the Wind River Range (WRR) on the Shoshone National Forest in west-central Wyoming. Ecological Types integrate vegetation and environmental characteristics, including climate, geology, landform, and soils, into a comprehensive ecosystem classification. The three objectives are: (1) complete field data collection, (2) simultaneously develop soil map unit components and Ecological Types, and (3) publish the ecological type classification such that it is compatible with the National Cooperative Soil Survey spatial and tabular data. Fifty-eight Ecological Types were organized into 3 ecosystems, 3 physiognomic groups, and 12 vegetation series.

***Keywords**:* ecological type, Wind River Range, National Cooperative Soil Survey, potential natural vegetation, Shoshone National Forest

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Looking west from Fairfield Hill—Left, Flathead Sandstone; Center, Gros Ventre Shale; Right, Gallatin Limestone outcrop. Photo by Aaron Wells.

This work is dedicated to the late Dr. Charles Grier Johnson, Jr.

Cover: Northeast Face of Gannett Peak from Dinwoody Creek, northeastern Wind River Range, Wyoming. Photo by Aaron Wells.

Contents

Introduction

The Wind River Range (WRR) is located in west-central Wyoming, occurring as a large massif of extensive forests, subalpine and alpine meadows, and alpine rock and ice, bounded on three sides by desert basins, including the Green River, Wind River, and Great Divide Basins (Figure 1). The WRR appears on a map of Wyoming as a southeasterly extension of the mountainous northwestern corner of the state, converging with the Absaroka and Gros Ventre Mountains in the north and northwest, respectively. The WRR is oriented along a northwest-southeast axis, extending southeasterly from Togwotee Pass in the northwest to South Pass, a distance of approximately 180 km. The width of the WRR depends on where one draws the line between mountains and desert basin. Based on vegetation, the distance from the meeting of sagebrush and forest on the west side to the meeting of sagebrush and forest on the east side is approximately 40 km (Kelsey 1988). Based on geology, the distance between the lower Cretaceous/upper Jurassic Cloverly and Morrison Formations near the town of Lander, Wyoming, to the easterly edge of the Eocene Green River Formation near the towns of Pinedale and Boulder, Wyoming, is approximately 81 km (USGS 1994).

The crest of the WRR forms the Continental Divide, and Three Waters Mountain (formerly Triple Divide Peak), located along the Continental Divide in the northern portion of the range, separates three major watersheds (Kelsey 1988), including the Upper Colorado, Missouri River, and Pacific Northwest (Columbia River) Regional Watersheds (Steeves and Nebert 1994). Precipitation falling to the east of Three Waters Mountain and the Continental Divide flows into the Wind River Basin via the Wind River, eventually emptying into the Missouri River in Montana by way of the Bighorn and Yellowstone Rivers. Bull Lake Creek, Dinwoody Creek, and Jakeys Fork are the major waterways in the northeastern WRR, while the Popo Agie (a Crow Indian word for "headwaters" and pronounced "po-PO-zhia") is the major river in the southeastern part of the range (Kelsey 1988). Draining the southern slope of the range, the Sweetwater River begins on the western slope and flows east, eventually joining with the North

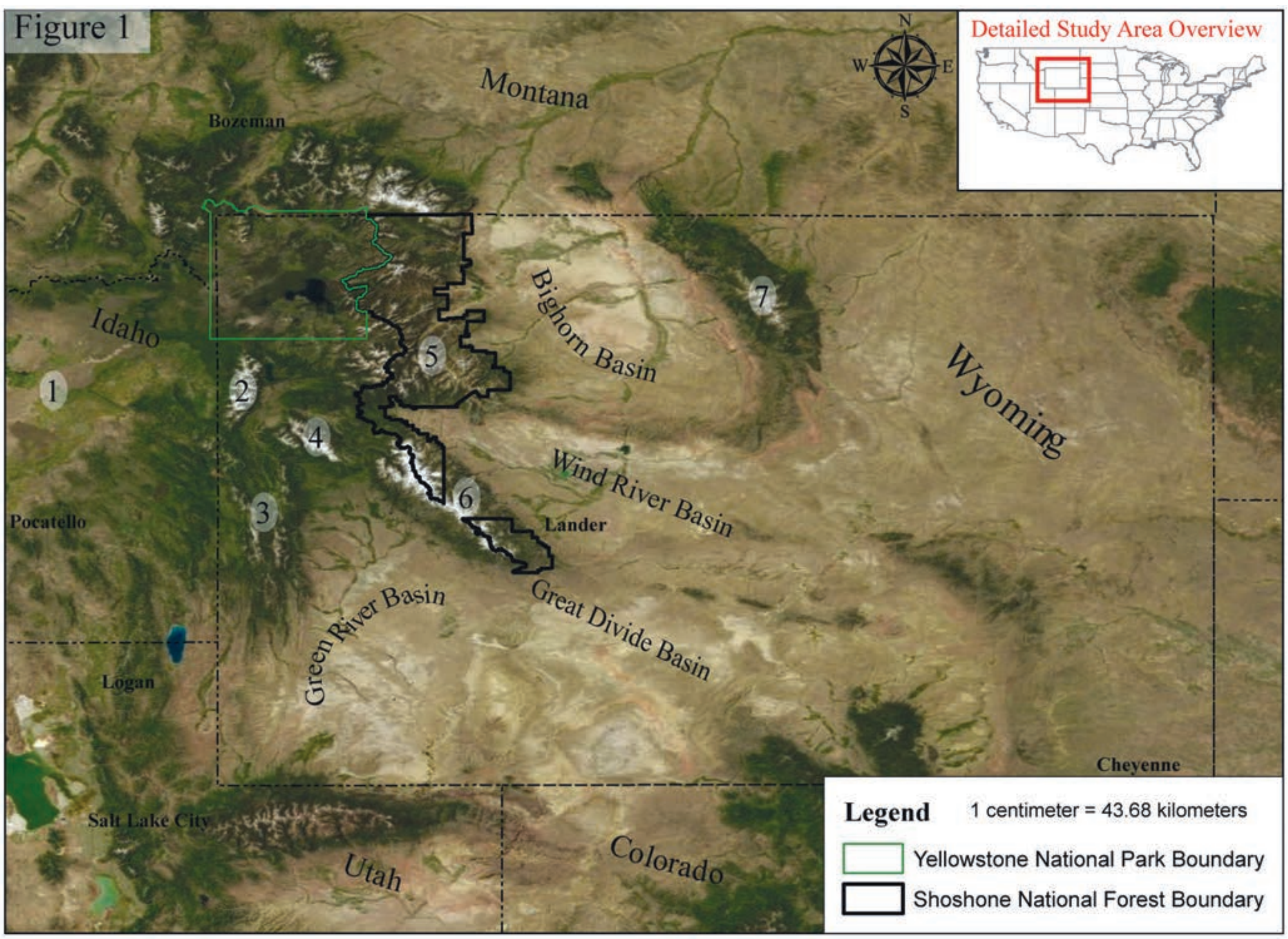


Figure 1—Overview map showing Shoshone National Forest within the broader landscape, including Wyoming and surrounding states (Paskevich 2002), major basins, and points of interest (POI). These POI include Snake River plain (1), Teton Range (2), Wyoming and Salt River Ranges (3), Gros Ventre Range (4), Absaroka Range (5), Wind River Range (6), and Bighorn Mountains (7). Background imagery from ESRI ArcGIS Online and data partners (ESRI 2012), Yellowstone National Park boundary from Department of the Interior (DOI 2008).

Platte River, which forms the Platte River in Nebraska and eventually flows into the Missouri River. Precipitation falling on the west slope of the Continental Divide, north of Three Waters Mountain, flows into Fish Creek, which empties into the Gros Ventre River, then to the Snake and Columbia Rivers. Precipitation falling on the west slope of the Continental Divide, south of Three Waters Peak, drains into the Green River Basin via the Green River, eventually emptying into the Colorado River. Major drainages on the southwest slope include Boulder and Pine Creeks and the New Fork River.

Vegetation of the WRR is quite diverse, as it includes a mixture of Central Rocky Mountain flora and species more typical of the Great Plains. At lower elevations (2100 to 2700 m), Rocky Mountain Douglas-fir forests occur on sheltered slopes, while limber pine woodlands, mountain big sagebrush, and Idaho fescue-bluebunch wheatgrass grasslands occur as a mosaic on more exposed slopes. Quaking aspen forests occur in moist upland sites, including topographic depressions and slumps, while willow communities dominate the steep, narrow riparian zones and wetlands. A subalpine zone, consisting of subalpine fir-Engelmann spruce forests and whitebark pine-Idaho fescue parkland occurs between 2700 m and timberline (approximately ~3200 m). Lodgepole pine forests occur within the subalpine zone on coarse-textured, unproductive soils, including those derived from sandstone and granitic glacial till. Above timberline lies the alpine zone, where turf communities composed largely of Ross' avens and blackroot sedge occur across broad windswept plateaus and narrow ridges. Grayleaf willow, tufted hairgrass, and Holm's Rocky Mountain sedge communities occur on moist, sheltered alpine sites.

The adjacency of the WRR with the Absaroka and Gros Ventre Mountains to the north results in connectivity between the mountains of northwestern Wyoming and the WRR, providing an important travel corridor for wildlife. Wildlife is abundant in the WRR, including grizzly and black bears, elk, white-tailed and mule deer, moose, pronghorn, cougars, Rocky Mountain bighorn sheep, beavers, muskrats, coyote, marmots, pikas, and a variety of song birds. Rocky Mountain bighorn sheep are most abundant in the northeastern portion of the range, north of Gannett Peak, where they spend the summer grazing on high alpine plateaus and summits near Whiskey Mountain and Ram Flat and winter on the extensive glacial moraines near Torrey Lake to the southwest of Dubois, Wyoming (Kelsey 1988). Trout, including cutthroat, golden, rainbow, and brook, are abundant in streams and in the thousands of glacial lakes scattered across the WRR (Mitchell 1999).

Objectives

Ecological Types integrate potential natural vegetation (PNV) and environmental characteristics, including climate, geology, landform, and soils, into a comprehensive ecosystem classification. The United States Department of Agriculture (USDA) Forest Service (USFS) has recently moved toward an ecological type approach to land classification termed the Terrestrial Ecological Unit Inventory (TEUI). TEUI is a field sampling protocol and ecological type classification system intended to collect information on the nature and distribution of ecosystems and to classify ecosystem types and map land areas with similar capabilities and potential for management (Winthers and others 2005).

The National Cooperative Soil Survey (NCSS) is a nationwide partnership of Federal, regional, state, and local agencies; and private entities and institutions (USDA NRCS 2007a). This partnership works to investigate, inventory, document, classify, interpret, disseminate, and publish information about soils of the United States. The USDA Natural Resource Conservation Service (NRCS) provides the leadership and data quality assurance for the NCSS.

The fieldwork for a NCSS of the Shoshone National Forest (SNF) was nearly completed as of the summer of 1997 with the exception of the eastern slope of the WRR.

<u>OBJECTIVE 1:</u> Complete the data collection phase of the NCSS on the SNF (Survey Area WY656) by finishing the fieldwork on the eastern slope of the WRR during the summers of 2004 and 2005 following NCSS and TEUI guidelines simultaneously.

Upon conclusion of the fieldwork on the eastern slope of the WRR, individuals from the NRCS, USFS, and Montana State University completed the NCSS of the entire SNF (USDA NRCS 2008). The end results of a NCSS are typically (1) a digital map of the soils depicting the spatial distribution of different soils organized into discernible map units, (2) soil tabular data, and (3) the classification of similar soil types, within soil map units, termed soil map unit components.

<u>OBJECTIVE 2:</u> Simultaneously develop the soil map unit component and ecological type classifications of the eastern slope of the WRR in order that the two classifications might be synonymous. The TEUI system of land classification had not been initiated into the USFS land survey protocols prior to circa 2000, and portions of the SNF completed prior to this were included only in the NCSS and not in the TEUI ecological type classification.

<u>OBJECTIVE 3</u>: Publish the ecological type classification of the eastern slope of the WRR. Primary to Objective 3 was the compatibility of this publication with the soil map unit spatial and tabular data from the WRR portion of the Shoshone National Forest NCSS (USDA NRCS 2008) and vice versa.

Classification Concepts

Definitions

The following are definitions of the major classification and mapping concepts used throughout this document.

Exact Joins–The goal of soil survey is a seamless product across political and physiographic boundaries. A seamless product entails an exact join of attribute and spatial data between soil survey areas. In some situations, an exact join may not be possible and an acceptable join is achieved (USDA NRCS 2007a). An exact join between soil survey areas occurs when soil polygon lines and features are continuous across and along the common boundary and joined soil polygons share the same basic soil properties and selected soil qualities. When accomplishing an exact join, soil map units from an adjacent soil survey may be brought into the survey area of interest (and vice versa) along the boundary of the two surveys if the soil and environment are similar. The map unit that is carried over into the survey area of interest is referred to in this report as a ”join unit.”

Ecological Type (ET)—An ecological type is a category of land with a distinctive combination of landscape elements, including climate, bedrock geology, landform, and soils, and differing from other types in the kind and amount of vegetation it can produce and in its ability to respond to management actions and natural disturbances (Winthers and others 2005). The ecological type concept is similar in many respects to the NRCS ecological site concept (Peacock, G.L., pers. comm.). As per Objective 2, major and minor Ecological Types correspond to the major and minor soil components, respectively. Note: In the Ecological Type Descriptions, major ETs ($n \geq 3$) are given an extended description including summary tables, while minor ETs ($n<3$) are given an abbreviated description written in paragraph form at the end of each respective vegetation series section.

Habitat Type (HT)—Originally defined by Daubenmire (1968) as “all lands capable of producing similar plant communities at climax.”

Potential Natural Vegetation (PNV)—The vegetation that would become established if all successional sequences were completed without human interference under present climatic and edaphic conditions (Winthers and others 2005).

Soil Map Unit (MU)—NCSS land unit classification concept that refers to a collection of areas defined and named the same in terms of their soil components and vegetation (Soil Survey Division Staff 1993). Each soil map unit differs in some respect from all others in a soil survey area and is uniquely identified on a soils map. A delineation refers to each individual polygon on a soils map. Soil map units consist of one or more components and/or miscellaneous areas. Soil components within a single map unit may be very similar or strongly contrasting depending on the degree of environmental heterogeneity included in the map unit. Soil surveys use four different kinds of map units to distinguish the degree of similarity-dissimilarity between components within a map unit (USDA NRCS 2007a). The four kinds of map unit (from most similar component soils to least) are:

Consociation—A single name representing the dominant component in the map unit is used to define delineated areas *and* highly dissimilar components are minor in extent.

Association—Includes two or more dissimilar soils that occur in a regularly repeating pattern within delineated areas *and* the major components of a complex can be mapped separately at the scale of mapping.

Complex (this study)—Includes two or more dissimilar soils that occur in a regularly repeating pattern *and* the major components (see below) of a complex cannot be mapped separately at the scale of mapping.

Undifferentiated group—Includes two or more components that are differentiated geographically and therefore do not consistently occur in the same map delineation.

Soil Map Unit Component or Component—Components of map units describe the properties of natural bodies of soils in a particular landscape (NSSC 2003). An individual component within a soil map unit embodies a collection of similar soils that represent a significant percentage of the land area of a soil map unit and occur repetitively across the landscape. Two types of components were defined:

Major component: A map unit component composing >10% of the areal extent of a map unit. A minimum of three sample points is required to define a major component. However, less than three sample points may constitute a major component if the component was also observed by the researcher to occur repeatedly across the landscape.

Minor component: A map unit component composing ≤10% of the areal extent of a map unit and having fewer than three sample points.

Nomenclature

Soil components were classified to an appropriate taxonomic classification using the 9th edition of the *Keys to Soil Taxonomy* (Soil Survey Staff 2003) and were then correlated to an existing soil series family name. The series family names were then used as part of the map unit and ecological type names. Occassionally, series family names were unavailable, in which case the soil subgroup of the typical pedon was substituted for the series family name (e.g., PSMEG/SYORU, Typic Calciustepts ET). The soil map unit components developed as part of the National Cooperative Soil Survey of the WRR portion of the Shoshone National Forest were used as the Ecological Types described in this management guide. However, cross-referencing between the soil map unit components and Ecological Types is not straightforward because the nomenclature between the two classification units differs slightly.

Soil Map Unit Nomenclature—Soil map unit complexes were named based on the soil components and miscellaneous areas (separated by hyphens) that compose the greatest percentage (>10%) of the land area in a map unit.

Soil Component Nomenclature—The map unit components were named based on soil series family names. Vegetation (PNV) phases were not used in the component nomenclature to differentiate between components.

Ecological Type Nomenclature—Ecological Types were given two-part names beginning with the vegetation (PNV) phase, including functional group (e.g., Late snowbank vegetation, Hargran Family ET), series (e.g., Lodgepole pine series, Corbly Family ET), or habitat type (e.g., subalpine fir/grouse whortleberry, McCall Family ET), followed by the soil series family name, followed by the abbreviation for Ecological Type (ET). Soils, geologic, geomorphic, and/or landform names were sometimes included in the name (in place of, or following the vegetation phase name and separated with a hyphen), thus indicating the importance of that landscape feature or process in the designation as an ecological type (e.g., Bluebunch wheatgrass-Sandberg bluegrass-mock goldenweed-Scabland, Paunsangunt Family ET; Oxyaquic soils, Elvick Family ET).

The one exception to the above naming convention was the mountain big sagebrush/Idaho fescue (ARTRV2/FEID), Corbly Family Ecological Type. The Corbly series family name was used as the series family name of an ARTRV2/FEID phase in both map units 351L (granitic glacial till) and 166D (granitic residuum). In order to differentiate between this vegetation phase in the two different map units, the following naming convention was applied: (1) ARTRV2/FEID, Corbly 351L Family ET for the map unit 351L component, and (2) ARTRV2/FEID, Corbly 166D Family ET for the map unit 166D component.

Synecological perspective and terminology

Traditional concepts in plant succession state that the most shade tolerant or "climax" species in a stand will come to dominate a given site in the absence of disturbance. The concept of climax potential reflects the most meaningful integration of the environmental factors affecting vegetation because it represents the end result of plant succession (Steele and others 1981). The term "habitat type" follows directly from the climax concept and is defined as all the land capable of producing similar plant communities at climax (Daubenmire 1968); this term has been adopted by authors of plant classifications across the Rocky Mountain West (Hansen and others 1995; Hironaka and others 1983; Pfister and others 1977; Steele and others 1981, 1983; Tweit and Houston 1980; Youngblood and Mauk 1985).

The climax concept is incorporated within the HT concept wherein the most shade-tolerant or, in the case of riparian zones and wetlands, water-tolerant (Wells 2006), species will prevail in the absence of disturbance. In this way, habitat types are not directly classified by the present assemblage of plant species; instead, classification is based on PNV, often times limited to the understory canopy layers or relatively sparse occurrences. Ecological Types incorporate PNV and the environment in an integrated classification. Ecological Types may include one or more similar HTs so long as the HTs included have similar PNV and occur within the relatively narrow range of environmental conditions defined by the ET.

Ecological unit classification

The framework of the TEUI is based on a National Hierarchy of Ecological Units (Cleland 1997). The National Hierarchy is a nested hierarchical land unit classification that begins by grouping land areas into broad classes based on large-scale (global, continental) climatic and physiographic factors. More detailed categories are then classified based on systematically smaller-scale (regional, local) climatic, geological, geomorphic, vegetative, and topographic factors (Winthers and others 2005). The classes within the National Hierarchy are (from broad-scale to fine-scale) (ECOMAP 1993):

Domain—An ecological unit in the ecoregion planning and analysis scale corresponding to subcontinental divisions of broad climatic similarity that are affected by latitude and global atmospheric conditions.

Division—An ecological unit in the ecoregion planning and analysis scale corresponding to subdivisions of a Domain that have the same regional climate.

Province—An ecological unit in the ecoregion planning and analysis scale corresponding to subdivisions of a Division that conform to climatic subzones controlled mainly by continental weather patterns.

Section—An ecological unit in the subregion planning and analysis scale corresponding to subdivisions of a Province having broad areas of similar geomorphic process, stratigraphy, geologic origin, drainage networks, topography, and regional climate. Such areas are often inferred by relating geologic maps to Kuchler (1964) potential natural vegetation groupings.

Subsection—An ecological unit in the subregion planning and analysis scale corresponding to subdivisions of a Section into areas with similar surficial geology, lithology, geomorphic process, soil groups, subregional climate, and potential natural communities.

The Ecological Unit Classification for this study follows Bailey (1995) for Domain, Division, and Province; Nesser and others (1994) and McNab and Avers (1994) for Section; and Chapman and others (2004) for Subsection (referred to as "Ecoregions").

Study Area

Overview

We present data and results from a soil and vegetation survey of the eastern slope of the WRR, Shoshone National Forest, Wyoming that was collected as part of a broader NCSS and TEUI of the entire Shoshone National Forest (USDA NRCS 2008). Figure 1 provides an overview of the Shoshone National Forest and surrounding areas. The study area was located along the southeastern two-thirds of the WRR, east of the Continental Divide and approximately south and east of Union Pass and Warm Spring Mountain (Figure 2). The study area encompasses a total area of approximately 191,021 ha. The study area splits the NCSS survey area for the Shoshone National Forest into two sections, including the study area for this report, and areas north of the study, referred to in this report as "study area" and "northern Shoshone National Forest," respectively. The Wind River Indian Reservation extends into the central portion of the east slope of the WRR and is not included in the study area, thus splitting it into northern and southern sections, referred to here as "northern study area" and "southern study area." The northern study area includes the area east of the Continental Divide to the Shoshone National Forest Boundary, and from approximately Union Pass and Warm Spring Mountain in the north to Hay Pass in the south. The southern study area includes the area east of the Continental Divide to the Shoshone National Forest Boundary, and from approximately Mount Hooker and the headwaters of the South Fork Little Wind River in the northwest to Bald Mountain and Dickinson Park in the northeast, to near South Pass in the south. The Ecological Unit Classification of the study area is presented in Figure 3 and Table 1.

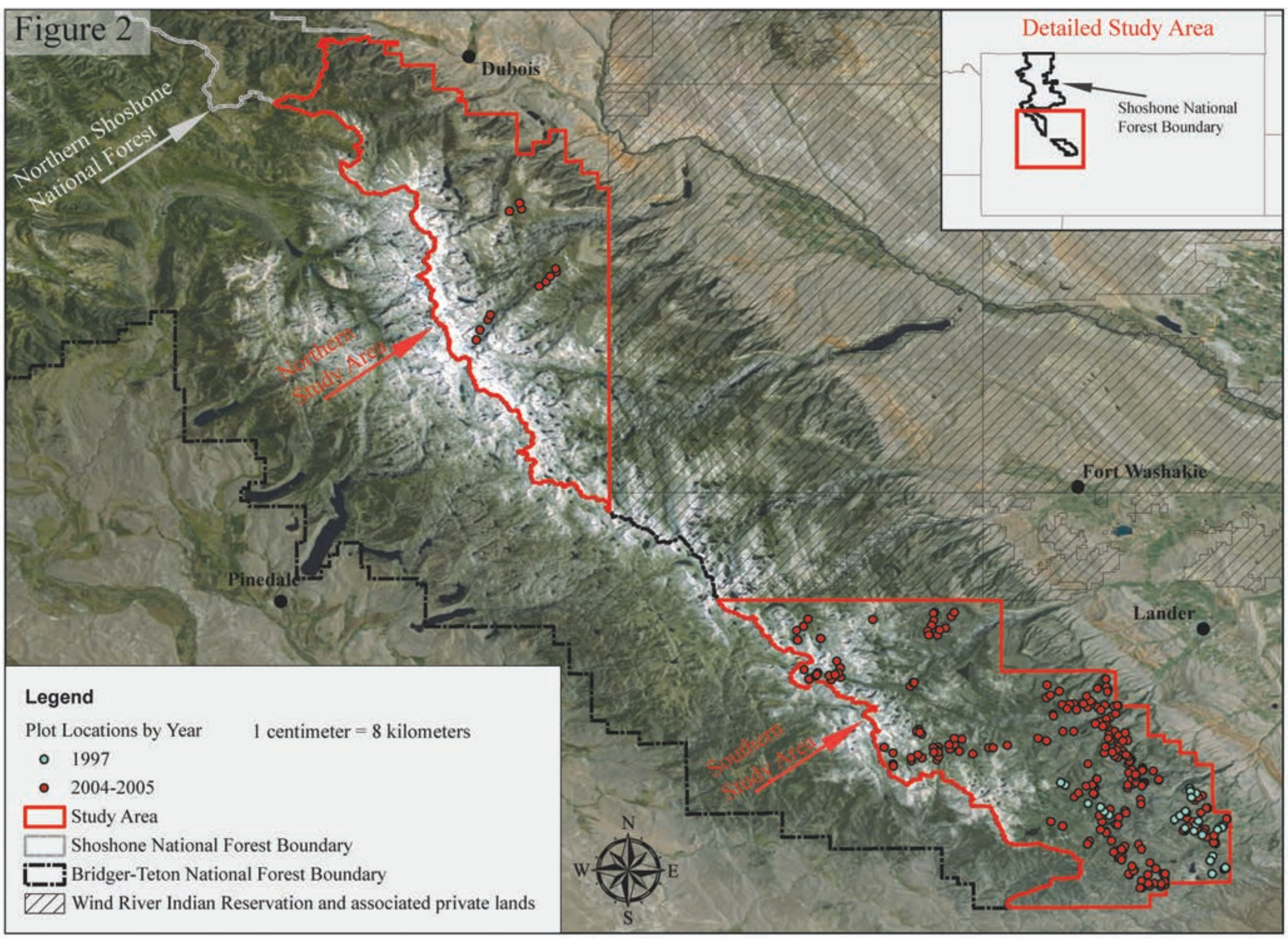


Figure 2—Detailed view of study area, including adjacent land ownership (BLM 2011) and field plot locations, ecological types of the eastern slope of the Wind River Range, Shoshone National Forest, Wyoming. Note: land ownership is incomplete and is not intended for navigational purposes. Always research land ownership and seek permission to travel across private lands. Background imagery from ESRI ArcGIS Online and data partners (ESRI 2012).

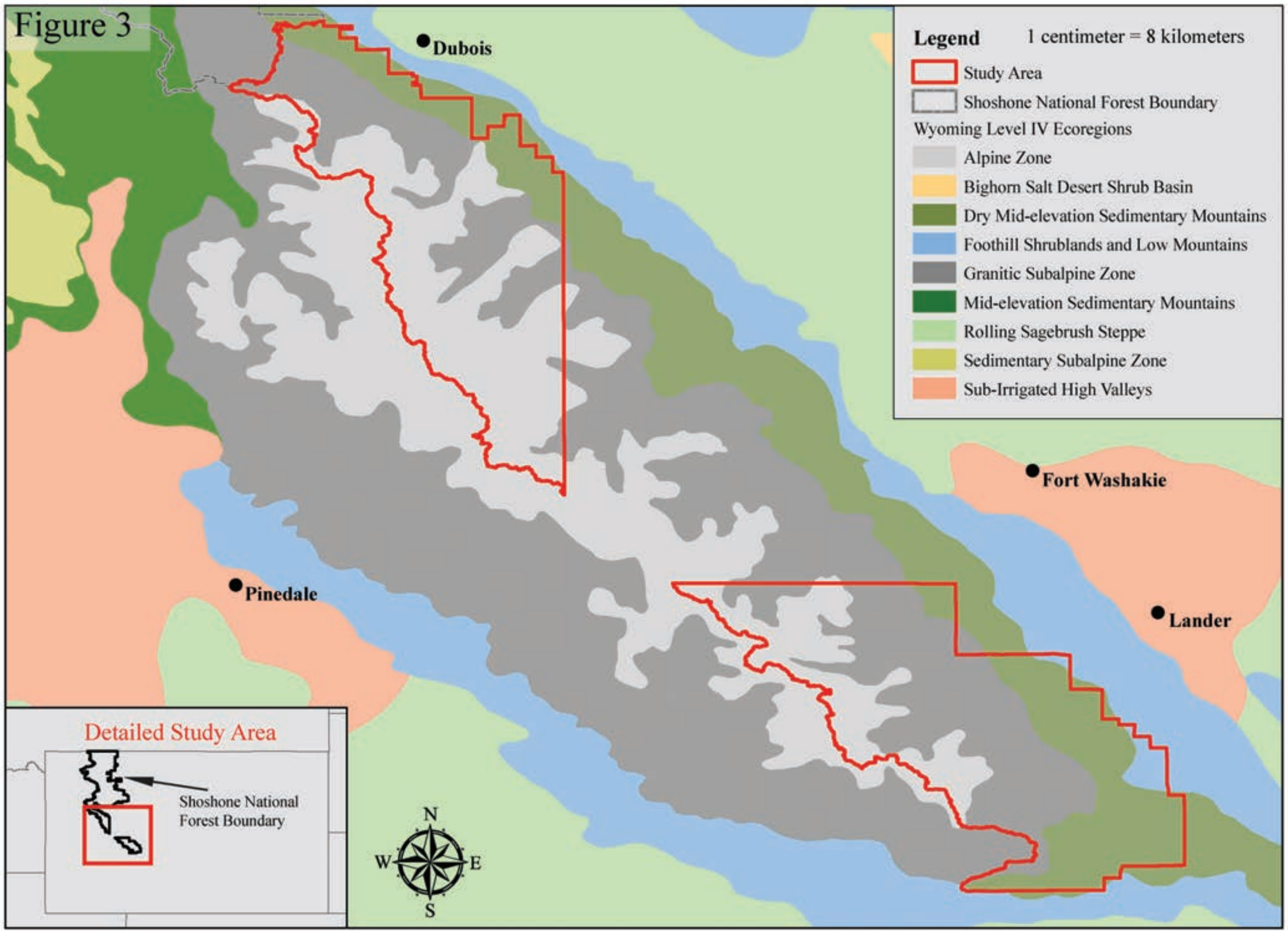


Figure 3—Detailed view of study area, including ecoregions of Wyoming (USEPA 2010), ecological types of the eastern slope of the Wind River Range, Shoshone National Forest, Wyoming.

Table 1—Ecoregion classification (Chapman and others 2004) of the study area, including map unit codes, the absolute (hectares) and relative (%) area of each subsection.

Domain – Dry (300)
- **Division –** Temperate Steppe Mountains (M330)
  - **Province –** Middle and Southern Rocky Mountain Steppe - Open Woodland - Coniferous Forest – Alpine Meadow (M331)
    - **Section –** Wind River Mountains (M331J)
      - **Subsection –** > Dry Mid-Elevation Sedimentary Mountains (17m, ~43,600 ha, 23%)
        > Granitic Subalpine Zone (17k, ~73,470 ha, 38%)
        > Alpine Zone (17h, ~70,930 ha, 37%)
- **Division –** Temperate Desert (340)
  - **Province –** Intermountain Semidesert (342)
    - **Section –** Central Basin and Hills (342F)
      - **Subsection –** > Foothills shrublands and low mountains (18d, ~3,020 ha, 2%)

Geology

The WRR occurs in the central portion of the Rocky Mountain cordillera as a large, north-south doubly plunging, asymmetrical anticline (Blackstone 1993). The WRR is bounded on the southwest by a series of reverse thrust faults, the most important of which is the Wind River fault (Figure 4). The present landscape of the WRR is the result of billions of years of geologic activity, including magmatism, tectonism, sedimentation, and erosion. The core of the WRR is characterized by Precambrian (Archean) crystalline basement rocks (Figure 5), including granodiorite, porphyritic quartz monzonite, and migmatic gneiss (Frost and others 2000). A series of Paleozoic and Mesozoic sedimentary formations along the eastern flank of the WRR abut the Precambrian rocks and dip consistently northeast at 10-15 degrees (Blackstone 1993). The South Pass Granite-Greenstone Belt is located in the southeast corner of the WRR and is a complex of Precambrian metasedimentary rocks, metamorphosed volcanic rocks, granodiorite plutons, and iron and gold deposits (Bayley and others 1973). Paleozoic sedimentary rocks abut the Greenstone Belt to the east, while Precambrian crystalline rocks and tertiary sedimentary rocks abut the Greenstone Belt to the north and south, respectively. During the Quaternary Period (please refer to Gibbard and others [2010] for latest Quaternary/Pleistocene stratigraphy), the WRR experienced cyclical glacial and interglacial periods. Over the course of hundreds of thousands to millions of years, the glaciers eroded the bedrock and stripped soil material from higher elevations, depositing these sediments at lower elevations in extensive moraine deposits.

The geology section is split into two subsections—the first presents a brief geologic history of the WRR, set within the broader geologic history of Wyoming; and the second presents detailed descriptions of the four major rock units in the WRR: (1) Precambrian, which includes the structural and magmatic history as related to the major Precambrian crystalline rock units; (2) The South Pass Granite-Greenstone Belt, including the geologic history of the area, and stratigraphy of major geologic rock units; (3) Paleozoic Sedimentary Formations, which includes information on the depositional setting, stratigraphy, and pertrology of major Paleozoic sedimentary strata; and (4) Glacial History and Till Deposits, which includes the glacial history of the WRR and descriptions of important moraine units across the eastern slope of the range.

Geologic history of the Wind River Range

The geologic history of the WRR is quite complex and spans a period of time difficult to comprehend. The brief description of this rich history, including major episodes and events, is intended to provide a general sense of the

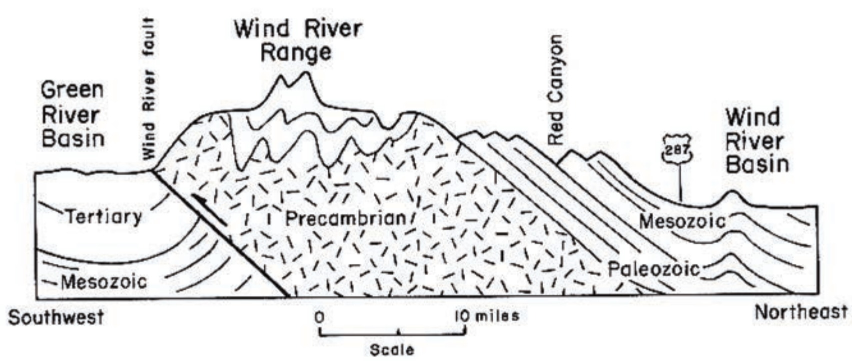


Figure 4—Schematic cross section of the Wind River Range, showing the Paleozoic sedimentary formations flanking the Precambrian igneous core and the location of the Wind River Fault. In this cross section, the Green River Basin is at about 2,195 m above sea level, the summit of the range at Gannett Peak is at 4,209 m, and U.S. Highway 287 in the Wind River Basin is at 1,677 m. Diagram from Figure 20 in Mears and others (1986) reprinted with permission from the Wyoming State Geological Survey.

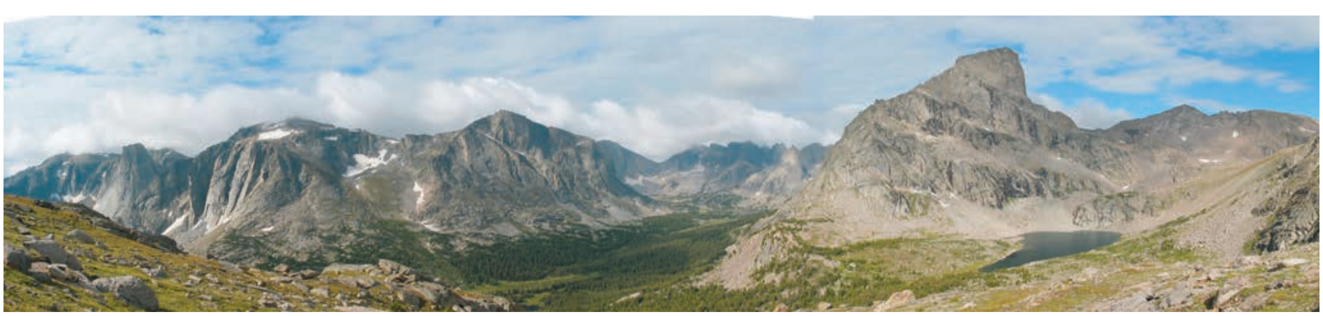


Figure 5—Looking west toward Lizard Head and Cirque of the Towers from Lizard Head Trail, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

Table 2—Geologic timeline of major geologic events in Wyoming (millions of years ago Ma).

EON	ERA	PERIOD	EPOCH	Ma[a]	MAJOR GEOLOGIC EVENTS IN WYOMING	Relative Timescale
Phanerozoic	Cenozoic	Quaternary	Holocene	NA	Recent times	Phanerozoic
Phanerozoic	Cenozoic	Quaternary	Pleistocene	1.6	Climate fluctuations, periodic ice ages	Phanerozoic
Phanerozoic	Cenozoic	Tertiary – Neogene	Pliocene	5.3	Yellowstone volcanic activity begins (2.2 Ma)	Precambrian
Phanerozoic	Cenozoic	Tertiary – Neogene	Miocene	23.7	Initial uplift of Teton Range Secondary uplift of the Wind River Range	Precambrian
Phanerozoic	Cenozoic	Tertiary – Paleogene	Oligocene	36.6	Initial uplift of Teton Range Secondary uplift of the Wind River Range	Precambrian
Phanerozoic	Cenozoic	Tertiary – Paleogene	Eocene	57.8	Formation of Absaroka Mountains (49-44 Ma) Laramide Orogeny (75-50 Ma)	Precambrian
Phanerozoic	Cenozoic	Tertiary – Paleogene	Paleocene	66.4	Formation of Absaroka Mountains (49-44 Ma) Laramide Orogeny (75-50 Ma)	Precambrian
Phanerozoic	Mesozoic	Cretaceous		144	Beginning of Sevier Orogeny (120-50 Ma)	Precambrian
Phanerozoic	Mesozoic	Jurassic		208	Nugget sandstone	Precambrian
Phanerozoic	Mesozoic	Triassic		245	Dinwoody Formation and Chugwater Group	Precambrian
Phanerozoic	Paleozoic	Permian		286	Phosphoria Formation	Precambrian
Phanerozoic	Paleozoic	Carboniferous – Pennsylvanian		320	Tensleep and Amsden Formation	Precambrian
Phanerozoic	Paleozoic	Carboniferous – Mississippian		360	Madison Limestone	Precambrian
Phanerozoic	Paleozoic	Devonian		408	Erosive period across much of Wyoming Province	Precambrian
Phanerozoic	Paleozoic	Silurian		438	Erosive period across much of Wyoming Province	Precambrian
Phanerozoic	Paleozoic	Ordovician		505	Bighorn Dolomite	Precambrian
Phanerozoic	Paleozoic	Cambrian		570	Flathead sandstone, Gros Ventre Shale, Gallatin Limestone	Precambrian
Precambrian	Proterozoic			2500		Precambrian
Precambrian	Archean			3800	Formation of rocks composing Wyoming Province	Precambrian
Precambrian	Hadean			4600		Precambrian

[a] Dates for geologic time periods from Figure 8-13 in Chernicoff and others (1997)

history and set the geologic framework within which the WRR was formed (Table 2).

The geologic history of Wyoming began more than 3 billion years ago (gigaannum, Ga) with the formation of a large portion of the Earth's crust termed the Wyoming Province, which was composed of late Archean migmatic gneiss, granite and plutonic rocks, ultramafic and mafic intrusive rocks, and a series of original sedimentary rocks subsequently metamorphosed (Snoke 1993). The Wyoming Province includes one of the oldest portions of the Earth's crust in North America, ranging in age from 2.5 to 3.4 Ga (Frost and Frost 1993). During this period in time, the area of the Wyoming Province that is now considered the WRR was located near the tectonically active margin of the Wyoming Province (Frost and others 2000). This area experienced a series of deformation and magmatic events that repeatedly reworked the Archean basement rocks.

Approximately 1.8 to 1.6 Ga, the Proterozoic aged Colorado Province accreted to the Wyoming Province in southeastern Wyoming, forming the tectonic boundary referred to as the Cheyenne Belt (Snoke 1993). The middle Proterozoic (1.5–1.4 Ga) across North America was characterized by a period of intense magmatism, which resulted in the intrusion of a swarm of mafic dikes across the Wyoming province, including the area presently considered the WRR. During the late Proterozoic (1300–570 million years ago [megaannum, Ma]), the Wyoming Province was a faulted upland characterized by erosion and deposition of sediments into adjacent basins in present day Utah and Colorado.

At the beginning of the Phanerozoic, during the Paleozoic and Mesozoic Eras, the Wyoming Province was inundated by an expansive inland sea that periodically regressed and transgressed (Snoke 1993). The periodic transgressions of the sea led to alternating sedimentation and erosion events and the eventual development of a broad, flat basin across the Wyoming Province termed the "marine foreland basin." During this time period, a diverse series of sedimentary formations, including marine, clastic, and eolian dune types were deposited across the Wyoming province, including the area that is now considered the WRR.

Two periods of intense magmatism and tectonic activity, termed the Sevier and Laramide Orogenies, occurred between the mid-Cretaceous and mid-Eocene Period (125–50 Ma). The Sevier (120–50 Ma) and Laramide (75–50 Ma) Orogenies were largely coeval, although the Sevier Orogeny began approximately 45 million years earlier than the Laramide (Frost, B.R., pers. comm.). The Sevier is defined as the thrusting of Paleozoic and Mesozoic sediments onto the Wyoming craton, which resulted in the formation of the fold and thrust belt, represented in the Wyoming Province by the Bear River, Salt River, Wyoming, and Gros Ventre Mountain Ranges of northeastern Utah, southeastern Idaho, and western Wyoming. The Laramide involved large uplifts within the Wyoming craton itself. Paleozoic and Mesozoic strata were fractured by faulting and upward displacement of Precambrian basement rocks, and the once broad, flat marine foreland basin was partitioned into a complex of structurally separated marine basins (Snoke 1993). A number of mountain ranges cored with Precambrian rocks were uplifted in Wyoming and across the Rocky Mountains, including the WRR, which was uplifted and thrust westward along the Wind River Thrust Fault. The total displacement on the fault was between approximately 9000 and 15,000 m (Frost, B.R., pers. comm.). Following the uplift, and westward thrusting, the crest of the WRR was composed of Cambrian sedimentary rocks and was located several kilometers west of the present topographic divide (Blackstone 1993). Although it is impossible to know the actual elevation of the crest of the WRR at that time, it is known that the elevation of the mountains was higher than that of present day and the basin floors were closer to sea level, resulting in dramatic topographic relief (Mears 1993).

Near the end of the Laramide Orogeny, during the mid- to late Eocene, another series of magmatic, tectonic, and volcanic episodes began in areas corresponding to the present day Absaroka Mountains (northwestern Wyoming), Black Hills (northeastern Wyoming), and Rattlesnake Hills (central Wyoming) (Snoke 1993). Also during the mid- to late Eocene, powerful tectonic and magmatic activity was tilting the Wyoming Province westward, reversing the eastward drainage and leading to the development of extensive lake systems in southwestern, central, and northern Wyoming, as well as parts of Utah and Colorado. A series of erosion and deposition events during the late Eocene to late Miocene resulted in the deposition of an extensive sheet of outwash, principally coarse volcanic debris, over a late Eocene landscape characterized by extensive late Eocene erosion. In the WRR, Precambrian crystalline basement rocks were exposed in the core of the range during this time due to continued uplift and erosion, and more than 3000 m of sediment had been eroded and deposited in adjacent basins.

During the Oligocene, intense volcanic activity occurred to the southwest, in the Great Basin Region (Mears 1993). Large volumes of volcanic debris, primarily airborne ash, fell over large areas of Montana, Wyoming, North and South Dakota, and western Nebraska. Deep ash deposits combined with continued erosion of the Precambrian crystalline basement rocks of the WRR throughout the Oligocene and early- to mid-Miocene led to rapid aggradation of adjacent basins and the development of an extensive low gradient erosion surface, or peneplane, of crystalline basement rocks along the periphery of the WRR (Mears 1993). At this point, the intense topographic relief of the early Laramide WRR was much subdued, and the range appeared more like a broad ridge with a series of isolated hills and mountain peaks protruding above a broad, flat Precambrian bedrock surface, than a continuous mountain range.

During the mid-Miocene, around the same time the Teton Range was initially uplifted, normal faulting during a regional tectonic event caused broad, regional uplifts that raised the WRR to its present elevation (Snoke 1993). The lifting of the once broad, flat erosion surface led to the eventual development of “high-level” or “summit” erosion surfaces (Mears 1993). However, the origin of the high-level erosion surfaces in the WRR is debatable, in fact a number of hypotheses exist. Please refer to Mears (1993) for a detailed discussion of these hypotheses. The high-level erosion surface was heavily eroded by glaciers during the Quaternary Period. However, remnants of this once broad high-level erosion surface (herein termed “high-level erosion surface remnants”) occur primarily in the northeastern portion of the WRR.

From the mid-Miocene regional uplift to the present, erosion events have dominated across the Wyoming Province, and a vast amount of sediment was stripped from the area presently considered the eastern Rocky Mountain Front (Snoke 1993). The most recent volcanic activity in the area of northwestern Wyoming, the area presently considered Yellowstone National Park, began during the early Pleistocene. The current Yellowstone Volcanic Plateau formed over the past approximately 2.0–2.5 million years, and was characterized by three major eruptions occurring 2.0, 1.3, and 0.6 Ma. Concurrent with the Yellowstone volcanic activity, the Rocky Mountains have experienced approximately 2.5 million years of periodic cooling cycles, resulting in a series of Ice Ages characterized by extensive glaciations in mountainous regions, alternating with warmer, drier periods. The erosion associated with these glaciations was extensive and has resulted in the fantastic topographic relief associated with the U-shaped glacial valleys, dramatic glacial cirques, and nunataks of the present landscape (Figure 6).

Major rock units

Precambrian granitics

The Precambrian history of the WRR began during the early Archean (>3.0 Ga) when much of the Wyoming Province was already formed of supracrustal rocks, primarily gneiss (Chamberlain and others 2003). The area of the Wyoming Province presently considered the WRR was located near the western margin of the Wyoming Province. The western margin remained both tectonically and magmatically active, resulting in continued crustal growth in the vicinity of the WRR throughout the mid- to late- Archean Eon. The Washakie Terrane in the northeastern portion of the WRR (Figure 7) is mostly 2.86 Ga; however, it contains inclusions of some of the oldest granitic rocks (3.3–3.8 Ga) in the WRR (Frost, B.R., pers. comm.). The Washakie Terrane is composed of relatively homogenous, banded gray gneisses (Frost and others 1998).

Figure 6—Looking north from the summit of Wind River Peak at 4,022 m. Photo by Aaron Wells.

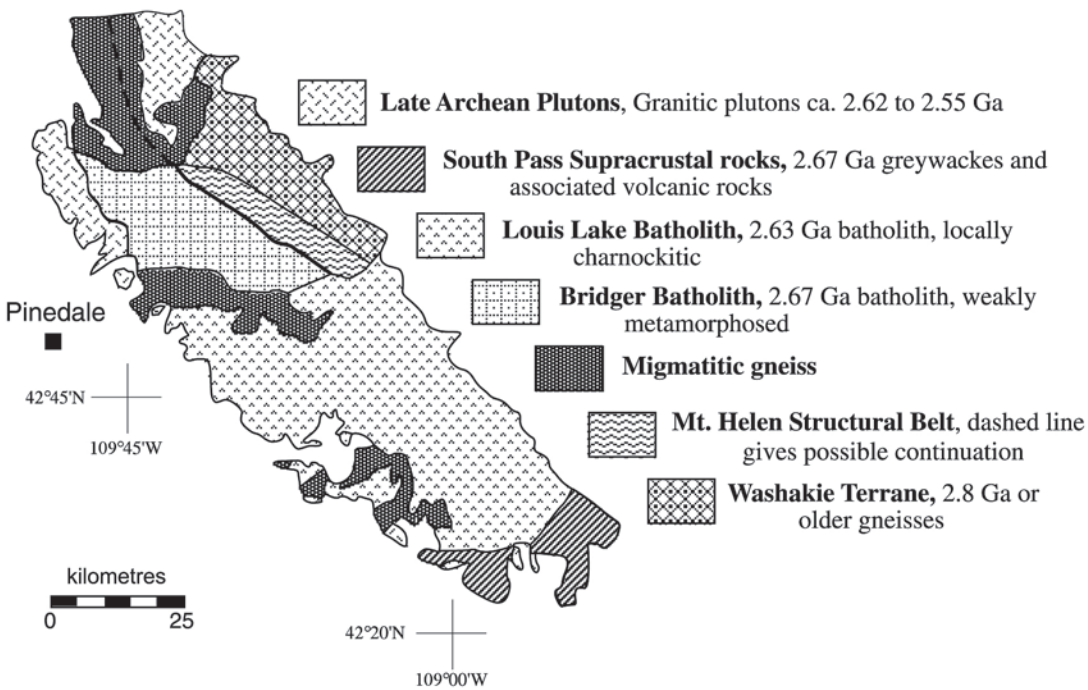


Figure 7—Geologic map of the Precambrian rocks of the Wind River Range. Diagram from Figure 2 in Frost and others (2006) reprinted with permission from B.R. Frost.

At approximately 2.8 Ga, the Native Lake Gneiss locally intruded broad areas of the northern WRR, including the Washakie Terrane, forming migmatite along the boundaries of larger intrusive bodies. The Washakie Terrane is the hanging wall of the Mount Helen Structural Block (MHSB), a thick uplift of supracrustal rocks characterized by a deep 45° normal fault to the southwest (Frost and others 2006). The MHSB creates the southwestern boundary of the Washakie Terrane, is 5 km wide, 40 km long, trends northwest, and occurs in the north-central portion of the WRR. The fault occurs on the southwestern boundary of the MHSB, beginning at the Continental Divide on the north flank of Mount Helen (approximately 4.2 km SSE of Gannett Peak) and extending 40 km to the southeast

(Granger and others 1971). The MHSB is composed of gneiss, intrusive bodies of porphyritic granite, and migmatite. It was formed when the Pacific plate began to subduct beneath the western margin of the Wyoming Province between 2.67 and 2.68 Ga. Subduction led to the eastward collision of the Idaho Continental Block with the Wyoming Province resulting in the southwest thrusting of the MSHB. Later during this same event, the Bridger Batholith, the product of melted mantle or subducted plate, intruded the western portion of the MSHB (Frost and others 2006). The Bridger Batholith comprises a large portion of the northwestern WRR and is composed primarily of granodiorite. Magmatism associated with the emplacement of the Bridger Batholith resulted in the formation of migmatite along its periphery.

The Louis Lake Batholith is the largest in the WRR and was originally emplaced in the southern half of the range around 2.63 Ga. Around this time, a series of late Archean batholiths were also emplaced in the northwestern and northeastern portions of the range and as isolated plutons in the South Pass area. The Louis Lake Batholith, south of the Middle Fork Popo Agie River, is primarily composed of granodiorite with localized intrusions of biotite quartz monzonite around Atlantic Canyon, Leg Lake, and the western ridge of Roaring Fork Mountain (Pearson and others 1971). Along Tayo Creek, near the headwaters of the Middle Fork Popo Agie River, a small (1.6 × 3.2 km) area of biotitic and hornblendic gneisses and schists with a core of albite-quartz crops out from the surrounding granodiorite. The portion of the Louis Lake Batholith north of the Middle Fork Popo Agie River is primarily porphyritic quartz monzonite, which is composed of large crystals of potassium-rich alkali feldspar set in a groundmass of oligoclase, quartz, biotite, and horneblende. Lastly, during the Proterozoic Eon (1.47 Ga), crustal extension across large areas of the Wyoming Province caused crustal thinning and rifting, resulting in the intrusion of diabasic dike swarms across the WRR (Chamberlain and others 2003). Individual dikes resulting from this episode are up to 50 m wide and 30 km long (Frost and others 2000). Although numerous smaller dikes occur throughout the WRR, four major dikes or groups of dikes exist along the eastern slope of the range. The first occurs in the southern portion of the Louis Lake Batholith, to the south and east of Louis Lake, where a series of dikes parallel and, at times, cross one another along a northeasterly trend (Pearson and others 1973). The second is a 23-km-long dike that begins on the southern slope of Wind River Peak and trends northeasterly toward Dickinson Park (Pearson and others 1971). The third is a pair of dikes that cross the continental divide near Baptiste and Grave Lakes in the northwestern corner of the southern study area. These two dikes run for approximately 32 km along a northeasterly trend, joining at a point approximately 8 km to the northeast of the Continental Divide. The fourth is the Goat Flat Diabase Dike, which occurs in the northeastern portion of the range, beginning near Native Lake in the southeast, extending northwesterly across Goat Flat, and crossing the Continental Divide near Triple Divide Peak (Granger and others 1971).

South Pass Granite-Greenstone Belt

The South Pass Granite-Greenstone Belt includes a series of metamorphosed Precambrian sedimentary and volcanic rocks that were thrust northward upon the Wyoming Province around 2.65 Ga (Frost and others 2000). The rocks of the South Pass Granite-Greenstone Belt are the result of sedimentation and intermittent volcanic activity on an ancient oceanic crust formed of basalts and ultramafic igneous rocks during the early Archean (2.72–2.64 Ga) (Frost, B.R., pers. comm.). The supracrustal rocks of the South Pass Granite–Greenstone Belt are unique among other supracrustal rocks in the WRR in that they present a logical stratigraphy due to the preservation of the primary sedimentary structure as a result of weak metamorphism (Frost and others 2000). The supracrustal rocks include five distinct rock units, from oldest to youngest: Gneiss Complex, Diamond Springs Formation, Goldman Meadows Formation, Round Top Mountain Greenstone, and the Miner Delight Formation (Bayley and others 1973; Hausel 1991).

The Gneiss Complex occurs along the border of the Louis Lake Pluton and the South Pass Granite–Greenstone Belt and consists of strongly foliated felsic gneiss, migmatite, granite, granodiorite, and amphibolite (Hausel 1988, 1991). Figure 8 provides a generarlized geologic map of the South Pass Granite–Greenstone Belt. The rocks of the Gneiss Complex have their origins as an early basement or supracrustal sequence that was adhered to the other South Pass supracrustal rocks by tectonic forces. The Diamond Springs Formation is located along the northern margin of the South Pass Granite–Greenstone Belt and originated as lava flows and sills that were erupted on an ancient sea floor during the Archean (Hausel 1991). The Diamond Springs Formation is composed of serpentinite, schist, and amphibolite. The Goldman Meadows Formation overlies the Diamond Spring Formation and occurs as a narrow, northeast trending band of rocks along its southeastern boundary. The Goldman Meadows Formation includes quartzite, schist, amphibolite, and a banded iron formation. The banded iron formation is a hard, dense, fine-grained, dark-colored rock consisting of alternating bands of magnetite and quartz (Bayley and others 1975). It is the product of chemical sedimentation followed by thermal metamorphism. The rocks of the Goldman Meadows Formation originated as sedimentary rocks formed from sediments deposited in a deep oceanic basin (Hausel 1991). The deposition environment was one of relative stability interrupted by periodic volcanic eruptions and subsequent basalt flows. The Round Top Mountain Greenstone overlies the Goldman Meadow Formation and occurs from Round Top Mountain in the northeast, southwest of the headwaters of Big Hermit Gulch. The Round Top Mountain Greenstone is composed of greenstone, greenschist, and amphibolite and originated as ancient ocean floor basalts cut by numerous basaltic and

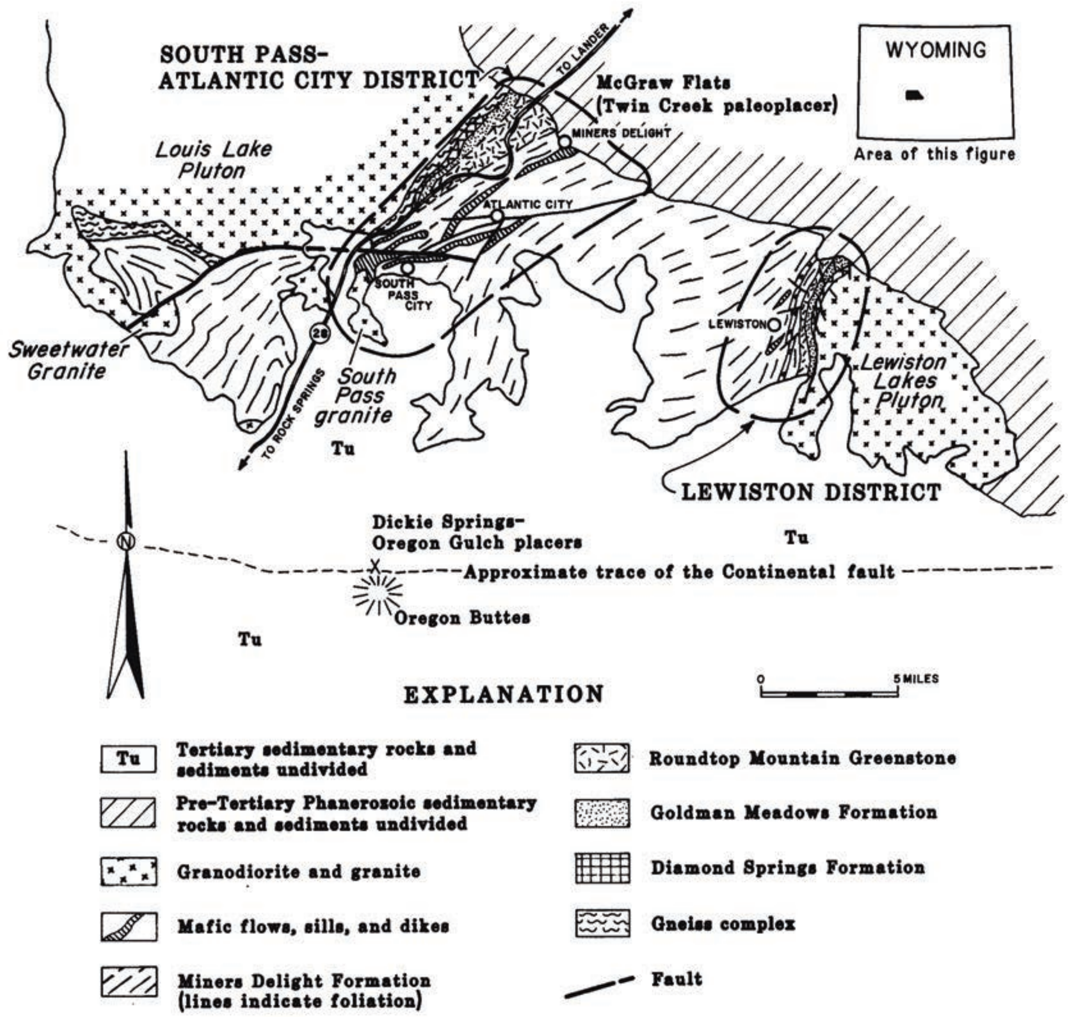


Figure 8—Generalized map of the South Pass granite-greenstone belt showing mining district locations, gold placers, and generalized Precambrian geology. Map from Figure 1 in Hausel (1991) reprinted with permission from the Wyoming State Geological Survey.

diabasic sills. Lastly, the Miners Delight Formation occurs across vast areas of the South Pass Granite–Greenstone belt and is composed primarily of metagreywacke interbedded with mica schist. The Round Top Mountain Fault, a major northeast trending fault in the South Pass area, marks the contact between the Miners Delight Formation and the Round Top Mountain Greenstone. The Miners Delight Formation originated as sediments deposited from a shallow water fan into a moderately deep oceanic basin.

The South Pass Granite–Greenstone belt also features a number of intrusive granite and granodiorite plutons that were emplaced around the same time as the Louis Lake Batholith (Hausel 1991). The Lewiston Lake Pluton was emplaced in the eastern portion of the South Pass Granite–Greenstone Belt during the first episode. During the second episode, a number of smaller, scattered plutons intruded the Miners Delight Formation in the western portion of the South Pass Granite–Greenstone Belt, including the South Pass Pluton located to the west of South Pass City and the Sweetwater Granite located along the Sweetwater River and Lander Creek.

Thick layers of sedimentary rocks, deposited during the Tertiary Period, cover about a third of the South Pass Granite–Greenstone Belt, including the Wasatch Formation, White River Formation, Arikaree Formation, and the South Pass Formation (Hausel 1991). The White River Formation occurs on the north slope of Round Top Mountain, overlying the Round Top Mountain Greenstone, and is composed of white to pale pink blocky tuffaceous claystone and lenticular arkosic conglomerate formed primarily from sediments of volcanic ash that blanketed much of the northern and central Rockies and western Great Plains during the Oligocene Epoch (see "Geologic History of the Wind River Range").

Paleozoic sedimentary formations

The sedimentary formations occurring along the eastern flank of the WRR and throughout central-western Wyoming and southwestern Montana were initially deposited during

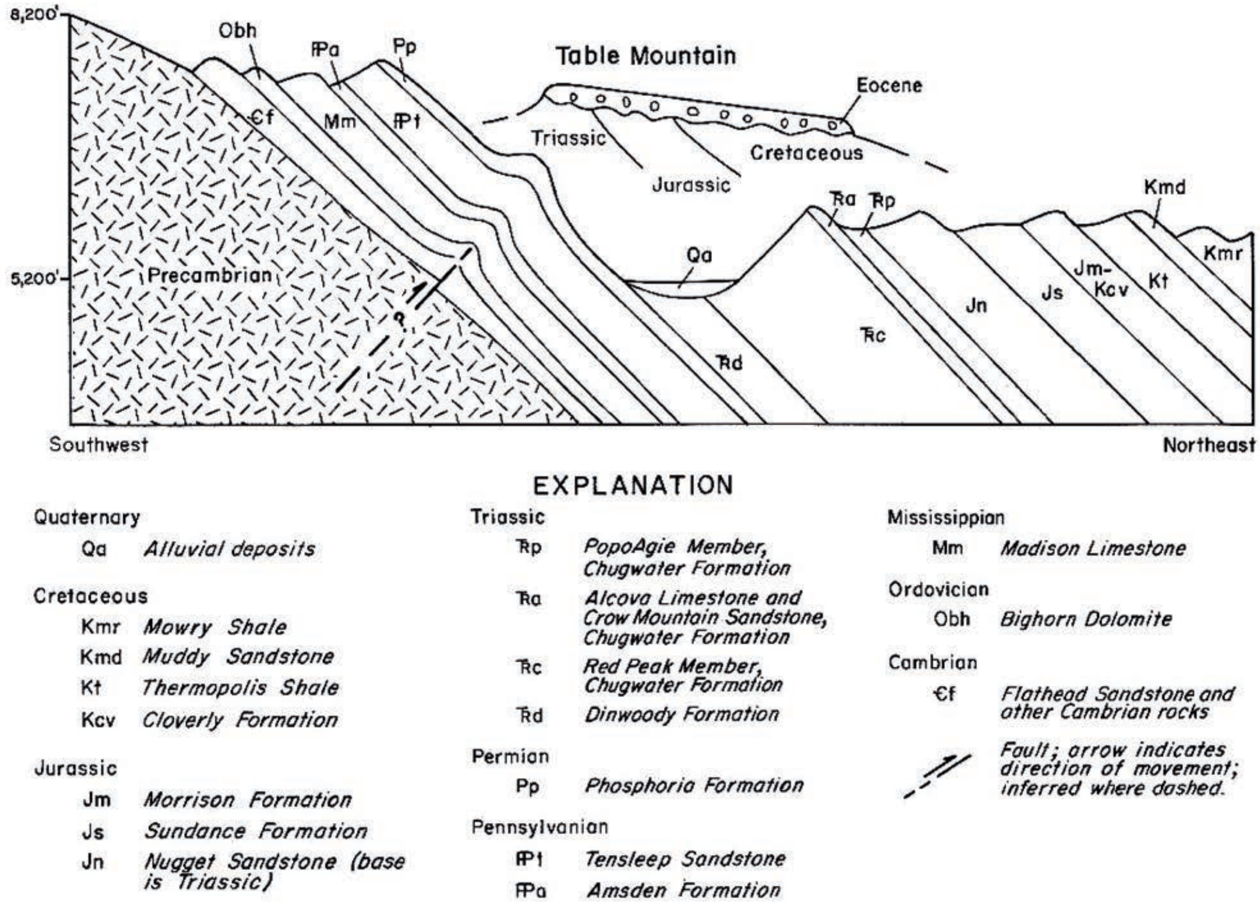


Figure 9—Schematic cross section of the southeast flank of the Wind River Range and western Wind River Basin, looking northwest from the head of Read Canyon. Section is about 11 mi across, and vertical relief at the surface is about 915 m. Diagram from Figure 21 in Mears and others (1986) reprinted with permission from the Wyoming State Geological Survey.

the Paleocene Era (570–286 Ma) when the area was part of a vast inland sea (Boyd 1993). The arrangement of the sedimentary formations atop one another reflects a series of depositional events associated with advances and retreats of seawater into and out of the area currently considered central Wyoming. Figure 9 illustrates the arrangement of sedimentary formations along the eastern flank of the WRR to the south of Lander, Wyoming near Red Canyon.

The oldest of the sedimentary formations, the Flathead Sandstone, is middle Cambrian (ca. 550 Ma) in age (Figure 10). Along the eastern flank of the WRR, the Flathead Sandstone rests on the Precambrian basement rocks of the core of the range and varies in thickness from approximately 50 m in the northwest to 90 m in the southeast (Bell and Middleton 1978). Two major rock units have been recognized in the Flathead Sandstone:
(1) the lower unit, characterized by medium-grained, clean sandstone that is locally shaley or conglomeratic at the base; and (2) the upper unit, characterized by parallel stratification with coarse- to fine-grained sandstone at the base grading upward into interbedded fine-grained, clayey sandstone, siltstone, and shale.

Figure 10—Flagstones of Flathead Sandstone, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

The middle to upper Cambrian (ca. 540–520 Ma) Gros Ventre Formation forms the next layer and exhibits a distinct scarp slope directly above the Flathead Sandstone. Throughout the majority of central and northwestern Wyoming, the Gros Ventre Formation is a thick (maximum thickness 250 m) shale-limestone-shale sequence (Boyd 1993). In order from oldest to youngest, the Gros Ventre Formation is divided into three members: Wolsey Shale, Death Canyon Limestone, and Park Shale (Middleton and others 1980). Along the eastern flank of the WRR, however, the Death Canyon Limestone is absent, thus preventing differentiation between the Wolsey and Park Shales. Where the Death Canyon Limestone is absent, the Wolsey and Park Shales are merged and collectively refered to as the Gros Ventre Group. The Gros Ventre Group consists of greenish-gray/purple-pink micaceous shale and ranges from cross-stratified sandy shale near the contact with the Flathead Sandstone to fine-textured shale interbedded with thin limestone toward the top.

Overlying the Gros Ventre Formation is the upper Cambrian (ca. 520–505 Ma) Gallatin Limestone Group, consisting of a limestone-shale-limestone sequence (Figure 11). The basal member of the Gallatin Limestone Group, the DuNoir Limestone, is a resistant, cliff-forming, massive, dark gray, locally sandy limestone averaging 30 m in thickness (Middleton and others 1980). The upper member of the Gallatin Limestone Group, the Open Door Limestone, is a cliff-forming, gray, coarsely crystalline limestone with thin interbeds of green shale and scattered flat-pebble conglomerates. The Open Door Limestone ranges in thickness between 21 and 80 m across central and northwestern Wyoming, trending toward the thinner end along the eastern flank of the WRR. Between the DuNoir and Open Door Limestones, along a sharp and erosional contact, lies the Dry Creek Shale Member of the Open Door Limestone. The Dry Creek Shale is dark-green, non-resistant shale interbedded with thin, pebbly limestone and fine-grained sandstone and siltstone beds. The Dry Creek Member is relatively thin, ranging between 7 and 16 m.

Figure 11—Gallatin Limestone outcrop, Limestone Mountain, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

Above the Gallatin Limestone Group lies the Ordovician (505–438 Ma) aged Bighorn Dolomite (Figure 12). Across central and northwestern Wyoming, the Bighorn Dolomite has been subdivided into four rock units, in order from oldest to youngest: Lander Sandstone, Steamboat Point, Leigh, and Horseshoe Mountain (Zenger 1992). Along the eastern flank of the WRR, the Steamboat Point Member has a gradational lower contact with the thin (1–1.5 m)

Figure 12—Bighorn Dolomite cliffs at Wild Iris Climbing Area, Limestone Mountain, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

Lander Sandstone Member, while the Leigh and Horseshoe Mountain Members are absent. The Steamboat Point Member is the most persistent and obvious member of the Bighorn Dolomite in the eastern WRR, forming prominent tan to yellow cliffs that vary in thickness between 32 and 54 m. Along the eastern flank of the WRR, the Steamboat Point Member is typically a uniformly fine-crystalline dolomite that essentially lacks "original" calcite. Unique to the Steamboat Point Member of the Bighorn Dolomite are irregular fretted surfaces, depressions, and sharp, sometimes knob-like protuberances (Johnson and Biggs 1955). The protuberances may have developed due to differential weathering of the less resistant dolomite matrix, resulting from the occurrence of scattered patches of more highly resistant quartz and opal rich dolomite. The irregular fretted surfaces have been attributed to the differential weathering of the dolomite matrix and the filled burrow cavities of the ichnogenus Thalassinoides (Zenger 1992). The more resistant surfaces are generally light-gray, fine crystalline dolomite, while the less resistant "matrix" is commonly pale yellowish to orange, coarser and more porous dolomite. Dust-like particles of iron-rich material sometimes occur within the interstices between the dolomite crystals, accounting for the pinkish to red tinge occasionally observed (Blackwelder 1913).

Silurian (438–408 Ma) aged rocks are absent along the eastern flank of the WRR due to heavy erosion during the Devonian Period (408–306 Ma). Following the erosional Devonian Period, the Mississippian Period (360–320 Ma) was characterized by thick carbonate deposition over a major portion of North America (Boyd 1993). Across much of Wyoming, the carbonate rocks of the Mississippian period have been given the name Madison Limestone (Figure 13). The Madison Limestone is a geologically diverse formation, with six members differing in ratio of limestone to dolomite, bedding type, grain origin, and chert content. Two formations are recognized in central Wyoming: (1) the older, Lodgepole Limestone (60–120 m; eastern flank WRR), rests conformably atop the Bighorn Dolomite and is characterized by basal black shale grading into cherty limestone; and (2) the younger, Mission Canyon Limestone (30–60 m; eastern flank WRR), is typically chert rich dolomite overlain by sandstone and red shale of the Amsden Formation (Andrichuk 1955; Boyd 1993).

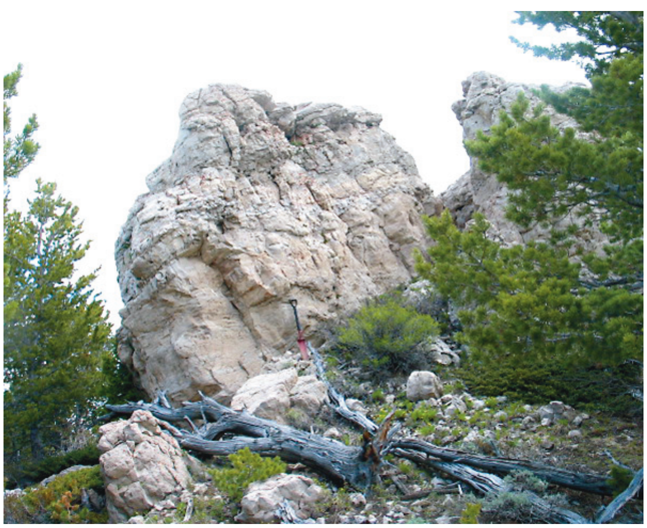


Figure 13—Madison Limestone outcrop on the summit of Peak 9239 in the Freak Mountains, east-central Wind River Range, Shoshone National Forest, Wyoming. "Sharpshooter" shovel in photo is approximate 1 meter tall. Photo by Aaron Wells.

The age and differentiation of the Amsden Formation has long been debated by geologists and has been referred to as the "Amsden Problem" (Boyd 1993). For the purposes of this discussion, the Amsden Formation will be considered late Mississippian (ca. 330–320 Ma) to early Pennsylvanian (ca. 320–310 Ma), and the original three-member sequence proposed by Darton (1908) will be employed. Lying disconformably atop the Madison Limestone Formation, the Darwin Sandstone (the first, and oldest member of the Amsden Formation) is a relatively thin (<30 m), friable, well-cemented, grayish-white to red, fine to medium grained, quartz sandstone (Sando and others 1975). The Horseshoe Shale member (average 25 m) rests conformably atop the Darwin Sandstone and represents the typical bright red to purple and graying fissile, platy, or blocky shale, siltstone, and mudstone often associated with the Amsden Formation. Calcareous quartz sandstone, silty to sandy limestone, and dolomite occur sporadically throughout the Horseshoe Shale member. Lastly, the Ranchester Limestone (average 30 m), the most widespread member of the Amsden Formation, exists between the top of the Horseshoe Shale and the bottom of the Tensleep Sandstone. The Ranchester Limestone is a heterogeneous sequence of interbedded cherty dolomite and limestone, sandstone, and shale.

The upper boundary of the Amsden Formation with the Pennsylvanian (ca. 310–286 Ma) Tensleep Sandstone is sometimes difficult to identify in areas where the Ranchester Limestone member is characterized by sandstone. The boundary between the Amsden and Tensleep is transitional and conformable, with inter-tonguing of Amsden and Tensleep common. The Tensleep Sandstone (15–100 m) is a white and cream to tan and pink, fine to medium grained, cross-bedded sandstone, sometimes interbedded with limestone and dolomite. Wind, rather than water, played a major role in transport and deposition of the sands that formed the Tensleep Sandstone, as evidenced by several eolian dune types, differentiated by distinctive bedding geometry, and grain characteristics (Boyd 1993).

Glacial history and till deposits

The Quaternary Period is characterized by a series of broad-scale climatic warming and cooling events, corresponding to interglacial and glacial oscillations (Table 3). At times during this period, an extensive ice sheet covered a large portion of the northern half of the North American continent, including the northern margin of the western

Table 3—Glacial timeline of the Wind River Range with approximate start and end times of important glacial and interglacial events (thousands of years ago Ka).

Period	Epoch	Climatic or glacial event		Glaciation	Start[a]	End	MIS	Source Articles	Relative Timescale
Quaternary	Holocene	Neoglaciation	Little Ice Age	Gannett Peak	500	150	1	Dahms (2002)	Holocene
				Black Joe	3000	1500	1	Dahms (2002); Dahms and others (2010)	
				Alice Lake	6000 - 5000	3,000	1	Dahms (2002); Dahms and others (2010)	
		Altithermal		Interglacial period	8,000	5,000	1	Davis (1988)	
	Pleistocene	Younger Dryas		Temple Lake	12,800	11,500	1	Gosse and others (1995b), Dahms and others (2010); Zielinski and Davis (1987)	
		Late Wisconsian		Pinedale	22,000	16,000	2	Dahms (2004a); Gosse and others (1995a); Phillips and others (1997)	Pleistocene
		Early Wisconsian		Intermediate Bull Lake/Pinedale	70 Ka	60 Ka	4	Hall and Shroba (1995); Pierce (2004)	
		Late Illinoian		Bull Lake	200 Ka	95 Ka	6	Chadwich and others (1997); Pierce (2004); Phillips and others (1997); Sharp and others (2003)	
		Early Illinoian and older		Sacagawea	770 Ka	660 Ka	16	Chadwick and others (1997); Hall and Jaworoski (1999)	
				Pre-Sacagawea	NA	NA	>16	Dahms (2004b)	

[a] All ages are approximate. Readers are encouraged to review the source articles for a more detailed discussion regarding the ages of glaciations.

United States. Across much of the western United States, south of the continental ice sheet, the Quaternary was characterized by episodic glaciations in the major mountain ranges of the Rocky Mountain Cordillera, including the WRR, corresponding to global glacial and interglacial intervals. The Marine Isotope Record (MIR) provides a continuous account of the Quaternary glacial and climatic history in a series of deep ocean sediment cores (Walker 2005). The MIR relies on the ratio of two oxygen isotopes, Oxygen-16 and -18, composing the marine microfossils found in the ocean floor sediments. The ratio of the heavier Oxygen-18 to the lighter Oxygen-16 depends on the amount of water frozen as glacial ice at a given point in time and is used to reconstruct historic climatic and glacial sequences (Dansgaard and Tauber 1969). The MIR has been classified into a series of stages, referred to as Marine Isotope Stages (MIS), reflecting the global glacial and interglacial intervals during the Pleistocene. The MIR indicates that worldwide in the past 800 thousand years (killaannum, Ka), there have been as few as 7 or 8 major glaciations and perhaps as many as 20 during the entirety of the Pleistocene Epoch (Pierce, K.L., pers. comm.). However, in glaciated landscapes, exposures of glacial till deposited by older glaciations are difficult to find as they are usually obliterated by subsequent glaciations (Gibbons and others 1984).

In the WRR, exposures of glacial till deposited by glaciations before MIS 14-12, referred to as pre-Sacagawea Ridge, are extremely rare (Dahms 2004a). Presently, pre-Sacajawea Ridge deposits have been eroded away or covered by till from subsequent younger glaciers and only small patches occur scattered throughout the range, occurring as deeply weathered and severely eroded mounds on high ridges and plateaus (Blackwelder 1915). The location of pre-Sacagawea Ridge till on high ridges and plateaus suggests that the physiography of the WRR was markedly different during these early glaciations (Holmes and Moss 1955). The dramatic U-shaped glacial valleys of today had not yet formed, and the range was a broad, high table land upon which large mountain icecaps developed. The lack of significant exposures of pre-Sacagawea Ridge till has made it difficult to directly collect information regarding the age and chronology of glacial-interglacial events during this time period. Richmond (1964, 1986) defined two pre-Bull Lake glacial deposits at Cedar Ridge along the northern shore of Bull Lake in the northeastern WRR, from oldest to youngest: Washakie Point (MIS 20) and Cedar Ridge (MIS 16-18). Hall and Jaworowski (1999) later reported soils and paleomagnetic evidence that the Washakie Point and Cedar Ridge deposits, as identified by Richmond, could not be confirmed and suggested that the terms should be abandoned. The Sacagawea Ridge till was redefined by Hall and Jaworowski (1999) for a small section of till that occurs near Dinwoody Lakes to the northeast of Bull Lake, given an age of MIS 16 (770–660 Ka), and remained as the sole pre-Bull Lake till until Dahms (2004b) reported patches of pre-Sacagawea Ridge till on a ridge above Sinks Canyon and on Table Mountain to the west of Lander, Wyoming. The pre-Sacagawea Ridge tills were not given numeric ages, but instead were defined as "younger" and "older" pre-Sacagawea Ridge units.

No surviving moraines are known between the Sacagawea Ridge glaciation and Bull Lake glaciation, but the MIR suggests that glaciations have occurred every ca. 100,000 years over the last 800 Ka and at shortened intervals to about 2 Ma (Pierce, K.L., pers. comm.). The Bull Lake glaciation was the next major glacial advance with known till exposures in the WRR and occurred between [200]>130 and 95 Ka (Chadwick and others 1997; Pierce 2004; Phillips and others 1997). The Bull Lake glaciation corresponds generally with the late Illinoian continental glaciations and MIS 6. During the Bull Lake glaciation, the topography of the WRR was approximately that of the present day, with deeply eroded U-shape glacial valleys, steep headwalls, and numerous nunataks standing above the glacial ice. The Bull Lake glaciers were extensive and spilled out into the surrounding basins. The most prominent of these glaciers, and the one for which Blackwelder (1915) originally named the Bull Lake till, occurred in the lower Bull Lake drainage in the northeastern WRR. Detailed studies of the extensive till deposits around Bull Lake and correlative outwash terraces along the nearby Wind River suggest that two to four separate, major Bull Lake glacial episodes occurred (Chadwick and others 1997; Sharp and others 2003). Bull Lake till is exposed near, and often extends beyond, the mouths of numerous canyons along the periphery of the WRR. Some of the more important of these include Bull Lake Creek (Blackwelder 1915), Dinwoody Creek, Jakeys Fork, and Torrey Creek (Applegarth and Dahm 2001) on the east side of the range, and near Fremont, Boulder, Willow, and New Fork Lakes on the west side of the range (Richmond 1987).

Preliminary evidence exists for exposures of till corresponding to a separate glaciation, intermediate between the Bull Lake and next youngest glaciation (Hall and Shroba 1995). This intermediate glaciation probably correlates with the early Wisconsian continental glaciation (ca 70–60 Ka), or MIS 4 (Pierce 2004). The early Wisconsian till was originally correlated with the Bull Lake glaciation, as the youngest of five Bull Lake aged moraines near Fremont Lake on the west slope of the range near Pinedale, Wyoming (Richmond 1987). Later, evidence arose around the Rocky Mountains for an early Wisconsian glaciation (Colman and Pierce 1986; Forman and others 1993) and further study progressed on the Bull Lake moraines at Fremont and Bull Lakes (Hall and Shroba 1995). As a result, the youngest of the five moraines at Fremont Lake previously correlated with the Bull Lake glaciation was reinterpreted and given the distinction as early Wisconsian. Limited exposures of early Wisconsian till have also been recognized in Sinks Canyon on the southeast slope of WRR (Dahms 2004b).

The next major glacial event in the WRR for which appreciable amounts of exposed till occur was termed the Pinedale glaciation by Blackwelder (1915) after till deposits occurring near Fremont Lake on the west slope of the range near Pinedale, Wyoming. Gosse and others (1995), using Beryllium-10 dating, found the age of the Pinedale glaciation to be between approximately 22,000 and 16,000 years, corresponding to the late Wisconsian continental glaciation and MIS 2 (Dahms 2004a). During the maximum Pinedale glaciation, the glacial ice extended down-valley to approximately 75–90% of the maximum Bull Lake glaciation. Pinedale till overlies or banks up against Bull Lake till on lateral moraines along the greater length of major glacial valleys along the western slope of the range, while Pinedale ice usually breached the Bull Lake moraines on the eastern flank of the range (Pierce, K.L., pers. comm.). Recession of the Pinedale ice corresponded with a warming period and occurred rapidly between approximately 16,000 and 12,100 years ago, during which time the glaciers receded an average of 33 km to their respective glacial cirques (Gosse and others 1995a; Pierce 2004).

The Temple Lake till represents a brief resurgence of glaciers that occurred during the Younger Dryas global cooling event between 12,800 and 11,500 years ago (Alley and others 1993; Gosse and others 1995b; Dahms and others 2010; Zielinski and Davis 1987). Temple Lake till is named after till deposits in a glacial cirque in the upper Temple Lake valley (Currey 1974; Miller and Birkeland 1974; Dahms and others 2010). Glaciers corresponding with the Temple Lake glaciation were relatively small compared to the Bull Lake and Pinedale glaciations and remained within glacial cirques in the high mountains. During the Younger Dryas event, tree line in the WRR was slightly lower than its present level and alpine tundra vegetation dominated glacial cirques (Fall and others 1995). Following the Younger Dryas, a transitional period occurred, and by approximately 10,340 years ago, the Temple Lake glaciers had receded to near their present positions near cirque headwalls, or had melted entirely. The first half of the Holocene Epoch was marked by warmer temperatures, including an interglacial period termed the "Altithermal" (Davis 1988). The Altithermal interglacial event occurred between approximately 8,000 and 5,000 years ago, with a maximum between approximately 7,200 and 6,400 years ago. During this warming event, tree line gradually shifted upward to a point 100 m higher than present day (Fall and others 1995). Subalpine forests composed of subalpine fir, whitebark pine, and Engelmann spruce dominated upper elevation forests, while Douglas-fir and cottonwood occurred as minor components of lower elevation forests. Near the end of the Altithermal, during the mid-Holocene, the climate began to cool, subalpine forests began to retreat to lower elevations near modern day tree line, and alpine tundra returned to glacial cirques.

The most recent series of glaciations, or Neoglaciation, began during the mid- to late Holocene, roughly 5,000 to 6,000 years ago, and was characterized by three glacial

Figure 14—Bonney Pass and Dinwoody Glacier from Gooseneck Pinnacle on Gannett Peak, northeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

events, including Alice Lake (6,000–3,000 yrs BP), Black Joe (3,000–1,500 yrs BP), and Gannett Peak (500–150 yrs BP) (Dahms 2002; Dahms and others 2010). The most recent of these, the Gannett Peak glaciation, occurred during the Little Ice Age (Naftz and others 1996). The glaciers of the Neoglaciation were smaller than the Temple Lake glaciers, and till from these glaciers formed a series of terminal moraines occurring successively higher within glacial cirques. Modern vegetation began to establish in the late Holocene, including alpine tundra (>3,200 m), whitebark pine parklands in upper elevation forests (3,100–3,200 m), subalpine forests in lower elevation forests (2,900-3,100 m), and the establishment of lodgepole pine across vast areas at lower elevations (Fall and others 1995).

The time since the end of the Little Ice Age (150 yrs BP) has been characterized by rapid recession of glacial ice and significant warming. Modern day glaciers are remnants of the Gannett Peak glaciation and are most abundant in the northeastern portion of the WRR, near Gannett Peak (Figure 14). In the southern portion of the range, small glaciers occur in glacial cirques on the north faces of Lizard Head and Wind River Peaks.

Sinks Canyon moraine

Sinks Canyon is located in the southern third of the WRR southwest of the town of Lander, Wyoming. Sinks Canyon is a popular destination for people visiting the eastern slope of the WRR due to easy access to public lands and abundant recreational opportunities. Sightseers are drawn to the famed "sinks" where the Middle Fork Popo Agie River disappears below the ground, only to resurface less than a 1 kilometer downstream. Rock climbers, horseback riders, backpackers, and mountain bikers flock to Sinks Canyon to test their mettle against the sheer dolomite cliffs or to access the many trailheads beginning in the upper sections of the canyon. Sinks Canyon is also unique both ecologically and geologically. The extensive mountain big sagebrush-bluebunch wheatgrass communities that occur here provide important winter range for mule deer, and the canyon is one of a few places where Utah juniper woodlands occur on the eastern slope of the WRR. Sinks Canyon may be unique geologically in that it might record a glacial history spanning more than 770,000 years, more than any other single location in the WRR. Given its unique nature, combined with high levels of human use, Sinks Canyon is subject to special management considerations. As such, a detailed description of its glacial history and stratigraphy follows.

Piedmont glacial deposits occur in many of the major canyons along the northeastern flank of the WRR, including Sinks Canyon, Bull Lake Creek Canyon, and Whiskey Basin (Applegarth and Dahms 2001; Dahms 2004b). Sinks Canyon was scoured through Paleozoic sedimentary rocks by glaciers flowing out of the present day Middle Fork Popo Agie drainage. The glacial deposits in Sinks Canyon possibly represent six different Pleistocene glaciations: Pinedale, early Wisconsin, Bull Lake, Sacagawea Ridge, and two pre-Sacagawea Ridge events (>770 Ka) (Gosse and others 1995a; Chadwick and others 1997; Philips and others 1997; Hall and Jaworowski 1999; Dahms 2004b; Pierce 2004). Pinedale age deposits are most extensive in the upper 9 km of the canyon, extending along the valley floor and lower valley walls from the terminal moraine at 2,037 m to a recessional moraine just up-valley from Popo Agie Falls (~2,642 m) (Dahms 2004b). In the canyon bottoms and lower canyon walls, the Pinedale deposits are overlain by mixed calcareous colluvium from the surrounding Paleozoic sedimentary outcrops. The majority of the early Wisconsin and Bull Lake moraines were buried by Pinedale deposits later in the Pleistocene, thereby limiting exposures of this material to narrow bands along the upper valley walls. In the lower reaches of the canyon, however, Bull Lake lateral moraines are exposed near the valley floor. The majority of the Sacagawea deposits are located beyond the mouth of Sinks Canyon, although patchy exposures occur north of Fossil Hill along the upper canyon walls. Lastly, the pre-Sacagawea deposits were laid down when the glacial ice flowed above the canyon rim and spilled out into the Wind River Basin. Pre-Sacagawea deposits occur exclusively beyond the canyon mouth and above the rim, the most extensive being the summit of Table Mountain and a section of the ridge running northeast of Fossil Hill near Deer Spring.

Louis Lake moraine

The Louis Lake moraine is located near Louis Lake, in the southern portion of the WRR, approximately 29 km southwest of Lander, Wyoming. The glaciers that formed the moraine flowed east from the Continental Divide near Silas and Atlantic Canyons and Christina Lake. The Louis Lake moraine is the main watershed of the Little Popo Agie River, a major tributary of the Wind River. The moraine terminates approximately 11 km east of Christina Lake at an elevation of roughly 2,550 m. Unlike moraines in other major drainages along the northeastern flank of the WRR, including Sinks Canyon, Bull Lake Creek Canyon, and Whiskey Basin, the Louis Lake Moraine does not extend outside the canyon mouth into the Wind River Basin. This may be the result of lower magnitude glaciations due to a warmer climate in the extreme southern WRR combined with a precipitation gradient that decreases to the southeast across the Continental Divide (see the "Climate" section). The vegetation on the Louis Lake moraine is primarily forested, with lodgepole pine at lower elevations and whitebark pine at upper elevations. Willow and sedge communities are common along the margins of kettle lakes. Alpine turf communities dominate in the glacial cirques.

The majority of the Louis Lake moraine downstream from the glacial cirques is composed of Bull Lake and Pinedale aged till. The Pinedale till ends just northeast of Louis Lake, where the remnant of the terminal moraine can be observed on a topographic map as a low ridge running north-south (Dahms, D.E., pers. comm.). The Bull Lake till extends another kilometer or so downstream where it ends in a fan-shaped terminal moraine. The lower one-third of the Louis Lake moraine is dominated by hundreds of tiny glacial lakes—termed kettle lakes—and alternating kames—or a low mound, knob, hummock, or short irregular ridge of glacial origin (Schoeneberger and Wysocki 2002). The kettle and kame topography, location near the terminal end of the moraine, and fan shape of the lower portion of the Louis Lake moraine may indicate that this section of the moraine is a glaciofluvial fan composed of stratified sands and gravels that were deposited by a subglacial stream at the margin of the melting glacier. The upper portion of the moraine is dominated by a series of terminal-recessional-lateral moraines. The outermost lateral moraines are most likely Bull Lake age, while the inner most lateral, terminal, and recessional moraines mark a series of glacial advances and recessions during the Pinedale glaciation. Two larger glacial lakes, Louis and Fiddlers, occur in the lower portion of the moraine (Dahms, D.E., pers. comm.). Both were dammed at least two times (Fiddlers Lake dammed at least three times) by lateral moraines of the Bull Lake and Pinedale glaciations (or older). In the glacial cirques, the moraine sequences follow those described for the WRR by Dahms and others (2010) and include till from late Pleistocene and Holocene glaciations, including Temple Lake, Alice Lake, Black Joe, and Gannett Peak.

Climate

Unlike the mountain ranges in the northern Rocky Mountains and Pacific Northwest, the WRR—located in the central Rocky Mountains, far from the maritime influence of the Pacific Ocean—experiences a cold, dry, continental climate regime. During the winter, arctic air masses carried by the jet stream regularly descend into central Wyoming, blasting the WRR with hurricane force winds and frigid temperatures. Also, the location of the WRR along the eastern Rocky Mountains Front Range places it in the rain shadow of numerous mountain ranges to the west. The result of the physiographic location of the WRR is that it is colder and drier than most of the mountain ranges in the northern and central Rocky Mountains and Pacific Northwest.

Precipitation

Ranges of precipitation in the following narrative are based on climate models of the entire Shoshone National Forest derived from weather station and grid-based climate data (see the "Climate Data—Modeled" section). The precipitation ranges reported in the text include modeled precipitation values from the lowest elevations in the study area in Sinks and Little Popo Agie Canyons (1,900 to 2,100 m) to the highest elevations (>4,000 m) along the Continental Divide. In addition to the below narrative, Appendix 1 provides summaries of 20 years of precipitation data from the USDA NRCS SNOTEL Climate stations at 4 sites across the study area ranging in elevation between 2,652 and 3,079 m.

Total average annual precipitation along the eastern slope of the WRR varies between 400 and 1,100 mm annually. The seasonal distribution of precipitation is highly variable and depends on broad-scale climate patterns along the eastern slope of the WRR. The broad-scale climate patterns observed along the eastern slope of the WRR reflect the geographic position of the WRR at the convergence of the Columbia River Plateau and the Great Plains and the orientation of the WRR perpendicular to the prevailing westerly winds. In general, a precipitation gradient occurs from higher precipitation in the northwest to lower in the southeast. A gradient in precipitation also occurs from west to east, with the greatest precipitation occurring at the Continental Divide and decreasing eastwardly.

During the winter months (December–February), Pacific storms originating in the Gulf of Alaska carry moisture-laden air from the Pacific Northwest across the Snake River Plain and into western Wyoming (Bryson and Hare 1974). In western Wyoming, this moisture-laden air encounters the Salt River, Wyoming, and Teton Ranges, and subsequently drops much of its moisture before meeting the WRR to the east. Upon uplift at the western slope of the WRR, a considerable portion of the remaining moisture precipitates, leaving the eastern flank of the range not only in a rainshadow but under the influence of drying, downslope winds.

During the late winter and spring (March–May), the northwesterly flows begin to weaken due to the northward expansion of tropical airstreams and the southward expansion of arctic air masses (Mock 1996). Moisture from the Gulf of Mexico is carried northward to the high plains of

Colorado and Wyoming by extratropical storms (Boatman and Reinking 1984). As a result, large precipitation increases are evident in the eastern high plains of Wyoming and eastern Front Range of the Rocky Mountains (Mock 1996), and the eastern flank of the WRR receives its highest amounts of precipitation (60 to 80 mm/month) in the form of rain and snow. Precipitation near the Continental Divide begins to decrease during the late winter and spring, ranging between 70 and 110 mm/month.

Precipitation generally decreases across the WRR during the summer months of June (45 to 65 mm), July (30 to 60 mm), and August (25 to 45 mm). Evapotranspiration is at a maximum during the months of June, July, and August, generally exceeding precipitation. The marginal precipitation that does occur during the summer is the result of convective thunderstorms that increase in frequency later in the summer.

September and October bring cooler temperatures and a slight increase in precipitation (35 to 80 mm/month), often in the form of snow. In November, the northwesterly storm systems resume, and precipitation increases to between 50 and 70 mm along the eastern flank of the WRR, and 70 and 125 mm near the Continental Divide (Mock 1996).

Temperature

Based on climate models of the entire Shoshone National Forest derived from weather station and grid-based climate data (see the "Climate Data" section), average annual temperature in the WRR varies between -5.1 °C at the highest elevations and 4.4 °C, at the lowest elevations. The study area experiences between 11 and 22 frost-free days each year.

The following discussion is based on USDA Natural Resource Conservation Service SNOTEL Climate station data from four sites across the study area ranging in elevation between 2,652 and 3,079 m (Appendix 1). The climate station data show some strong seasonal trends across all four sites. The coldest months are typically December, January, and February, with average daily temperature across the sites ranging between -7.9 and -7.1 °C, and average daily minimum temperatures commonly dipping below -12 °C during the winter months. Temperatures begin to warm up beginning in March through May, with average daily temperatures across the sites ranging between -1.5 and 0.5 °C during the spring months. June, July, and August are historically the hottest months, with average daily temperatures ranging between 10.2 and 12.1 °C, and average daily maximum temperatures often exceeding 21 °C during the summer months. Beginning in September through November, temperatures begin to cool down again, with average daily temperatures across the sites ranging between 0.7 and 1.9 °C during the fall months.

The South Pass SNOTEL climate station (2,756 m) is the most southerly climate station in the WRR. Average daily temperature was 1.4 °C during the period between 1986 and 2006. Average annual maximum and minimum temperatures were 9.8 and -5.1 °C, respectively. Two years out of 10, the average annual maximum temperature was greater than 14 °C, while the average annual minimum temperature was less than -9 °C.

The Townsend Creek SNOTEL climate station at 2652 m is the lowest elevation climate station in the WRR. Average daily temperature was 1.9 °C from 1990 to 2006. Average annual maximum and minimum temperatures were 10.3 and -6.3 °C, respectively. Two years out of 10, the average annual maximum temperature was greater than 15 °C, while the average annual minimum temperature was less than -11 °C.

The Hobbs Park SNOTEL climate station at 3,079 m is the highest elevation climate station in the WRR. Average daily temperature was 0.4 °C between 1990 and 2006. Average annual maximum and minimum temperatures were 7.0 and -6.1 °C, respectively. Two years out of 10, the average annual maximum temperature was greater than 11 °C, while the average annual minimum temperature was less than -11 °C.

The Cold Springs SNOTEL climate station is the most northerly climate station in the WRR and the second highest at 2,935 m. Average daily temperature was 1.0 °C between 1990 and 2006. Average annual maximum and minimum temperatures were 7.8 and -4.6 °C, respectively. Two years out of 10, the average annual maximum temperature was greater than 12 °C, while the average annual minimum temperature was less than -9 °C.

Topography and climate

Topography significantly influences climate patterns along the eastern slope of the WRR, where the annual precipitation is near the lower tolerance limits of forested plant communities. Slight changes in topographic position influencing precipitation, temperature, and solar radiation patterns affect the amount of soil water available during the growing season. In turn, the vegetative potential of a site may seem to be disproportionately affected with a physiognomic shift from, for example, grassland to woodland. Elevation in the WRR varies between 1,931 m in the depths of Little Popo Agie Canyon, to the highest point in Wyoming, the 4,207 m summit of Gannett Peak, in the northern part of the range. Upper tree line averages around 3,200 m and varies between 3,100 and 3,200 m depending on slope aspect and latitude. A lower tree line of approximately 2,400 m occurs on south-facing slopes and is extended downward to 2,100 m on north-facing slopes.

Elevation has an inverse relationship with temperature and the number of frost-free days, while precipitation tends to increase with increasing elevation (Baker 1944). In the mountains of Wyoming, air temperature generally decreases at a rate of approximately 3.5 ºC per 300 m in dry air (2 ºC in saturated air) (Curtis and Grimes 2004). In mountainous topography, temperature inversions may result in cold air drainage when nighttime (cooler) air of the upper slopes, having greater density than warmer air, drains down ravines and slides under the mass of warm air that has accumulated in the valley during the day (Lee 1978).

Aspect can mimic elevation affects depending on slope orientation (Barry and Van Wie 1974). Northerly slopes tend to experience lower solar radiation input and thus lower evapotranspiration, cooler temperatures, fewer frost-free days, and higher available soil water throughout the growing season. Southerly slopes experience higher radiation inputs and thus higher evapotranspiration, warmer temperatures, more frost-free days, and lower available soil water throughout the growing season.

In montane environments, aspect and the direction of the prevailing winds play a role in the movement and deposition of the winter snow pack (Johnson and Billings 1962). Windward slopes, receiving the full force of the prevailing winds, are areas of net snow loss during the winter months and thus have lower available water throughout the growing season. Leeward slopes, protected from the prevailing winds, are areas of net snow accumulation and thus have higher available water throughout the growing season. The duration of snow cover is directly influenced by the direction of the prevailing winds and slope aspect. Windward slopes accumulate little to no snow and typically melt off early, while leeward slopes accumulate deep snow drifts and melt off later in the season or not at all. Southerly slopes receive higher levels of radiation and melt-off earlier than more sheltered, north-facing slopes.

Climate change and the Wind River Range

This section contains a brief synopsis of the potential impacts of climate change in the WRR. For an in-depth review of climate change on the Shoshone National Forest, please refer to Rice and others (2012). The Earth is no stranger to climate change. One need only look at the glacial record of the WRR, which depicts a cycle of climatic warming and cooling events corresponding to interglacial and glacial periods throughout the last 2 million years. Climate cycles, including the present interglacial period, are natural phenomena that have occurred throughout the Earth's history. Whether climate change is actually occurring, or the degree to which it is natural versus human-induced, is not the subject of this discussion, and readers interested in this topic may refer to IPCC (2007) for more information. For the purposes of this discussion, it is assumed that climate is changing, and that it is happening at an accelerated rate relative to historic levels (ca. pre-1950), and it will continue to occur throughout the Twenty-First Century. Unprecedented climate warming has occurred worldwide during the later half of the Twentieth Century and the beginning of the new millennium and is nearly double that for the past century. Since 1978, Arctic sea ice has melted at a rate of nearly 3% per decade (IPCC 2007). Furthermore, estimates based on changes in length of 48 glaciers from around the world suggest that mountain glaciers declined by an average of 1.23 km during the 94 years between 1884 and 1978 (Oerlemans 1994).

In the WRR, estimates gathered from ice core data from Upper Fremont Glacier indicate that average air temperature increased by 2.1 °C between 1985 and 1991 relative to the estimated air temperature during the Little Ice Age, more than three times the increase that occurred over the 90-year period immediately following the Little Ice Age (Naftz and others 2004). A consequence of the climate warming is that glaciers in the WRR, as in other parts of the world, are rapidly melting. Using repeat photography, Marston and others (1989) documented the changes in Gannett and Dinwoody Glaciers, located in the northeastern WRR, between 1935 and 1988. The photos showed that during the 53-year period, both glaciers experienced significant termini retreat to upper cirque positions. Naftz and others (2008) attributed a glacial outburst flood that occurred in 2003 at Grasshopper Glacier, located to the north of Gannett Peak, to rapid melting of the glacier due to accelerated warming. Although current climate models do not have the resolution to model alpine areas of limited areal extent, such as those in the WRR, it is likely that the large temperature increases observed in the past will continue into the future, given the projected increases in CO_2 over the next 50 years (Naftz, D.L., pers. comm.).

Glacial melt-water provides a reliable source of late summer water for residents of the Wind River Basin (Marston and others 1989). The effects of a reduced water supply due to shrinking glaciers may have far reaching effects, from local irrigation to multi-state water agreements. Rapid melting of glaciers may result in an increased frequency of glacial outburst floods that pose a risk to humans residing or recreating in the valleys downstream (Naftz and others 2008). Lastly, the WRR has a rich history of mountaineering that continues today (Kelsey 1994). The glaciers that play a large role in that history may themselves become history as air temperatures continue to rise.

Continued warming throughout the Twenty-First Century may result in a higher incidence of insect and disease outbreaks in forested communities across North America (Logan and others 2003). In the WRR, this is particularly true in lodgepole and whitebark pine communities. Nearly pure stands of lodgepole pine occur on the Tensleep and Flathead Formations and on lower elevation (approximately 2,600 to 2,900 m) glacial deposits, while extensive whitebark pine stands occur near timberline (approximately 3,000 to 3,200 m). Lodgepole pine and whitebark pine are favored host species for the mountain pine beetle (MPB; *Dendroctonus ponderosae*), a bark beetle that has infested millions of hectares of pine forests in the western United States and Canada (Logan and Powell 2001; USDA FS 2004; Westfall 2004). In order for large MPB outbreaks to occur, the insects must attack en masse by combining synchronous emergence during favorable temperatures with a one-year life cycle, a combination of life history attributes termed "adaptive seasonality" (Hicke and others 2006). Using temperature data for the period between 1895 and 1993, Hicke and others (2006) modeled adaptive seasonality of MPB across the western United States in relation to the distribution of lodgepole pine. The model showed a large gap in adaptive seasonality in the northwestern corner of Wyoming, to include the WRR. The gap in northwestern

Wyoming is due to the higher elevations and cold, continental climate of the area and particularly the WRR (Logan, J.A., pers. comm.). When the model was expanded to include future climate warming, the model predicted an increase of 5 °C by the year 2100 and a decrease in the area of adaptive seasonality, mostly due to lower elevations becoming too warm to foster adaptive seasonality in MPB (Hicke and others 2006). The model predictions suggest that while warmer, lower elevation forests are seeing a reduction in adaptive seasonality, a warming climate would result in an increase in the area of adaptive seasonality and perhaps an increased risk of episodic MPB attack in the relatively higher elevations of the WRR (Logan, J.A., pers. comm.). Lodgepole pine stands on the Tensleep and Flathead Formations and on lower elevation (approximately 2,600 to 2,900 m) glacial deposits would likely be most vulnerable as they are located at relatively warmer, lower elevations.

Throughout its range, whitebark pine is a foundation species that serves a number of essential ecosystem functions (Ellison and others 2005). Whitebark pine stands near timberline, historically too cold to support adaptive seasonality, may also be at risk of catastrophic MBP outbreaks with continued warming. Compounding the problem for whitebark pine is an increased occurrence of white pine blister rust (*Cronartium ribicola*), an exotic fungal pathogen that is lethal to five-needle pines and that will likely accompany a warming climate (Koteen 2002). Historically, whitebark pine was thought to be safe from severe outbreaks of blister rust due to the cold, dry conditions inhabited by this timberline species. However, recent observations by Resler and Tomback (2008) of white pine blister rust in high elevation, krummholz whitebark pine of Glacier National Park, Montana, may indicate otherwise. The decline of whitebark pine in the WRR due to climate change would have dramatic effects, ranging from snowpack water retention to the population dynamics of grizzly bears (Koteen 2002; Ellison and others 2005).

A warming climate is also likely to change wildfire dynamics in the WRR and across the western United States. Westerling (2006) found that during the period between 1986 and 2003, the total area burned by wildfires in the western United States increased 6.5 times compared to the previous 16 years. Fire frequency was also found to have increased by four times during the same period. Some of this increase in area burned and fire frequency was attributed to increased fuel loads due to fire suppression over a large part of the Twentieth Century. However, climate warming was found to have a significant effect on the wildfire occurrence and extent. For instance, earlier snowmelt corresponding to a warming climate was positively correlated with increased fire frequency. Exacerbating the effects of earlier snowmelt dates on fire frequency is increased fuel loads that are sure to accompany massive mountain pine beetle infestations.

Another change that may accompany a warming climate is a shift in lower elevation grasslands and sagebrush communities from cool season bunchgrasses of mesic habitats, such as Idaho fescue, to cool season bunchgrasses of more xeric regimes, such as bluebunch wheatgrass. Lower and upper timberline, currently located at approximately 2,100 and 3,200 m, respectively, are likely to gradually shift upward. Pikas (*Ochotona princes*), the small rodents whose distinctive squeak signals a hikers entrance into the alpine zone, will face an uncertain future as the climate continues to warm (Beever and others 2003). Lastly, as the climate continues to warm, alpine plant species will be pushed to higher elevations in order to maintain the cold temperature conditions required for their survival. It is likely that at some point, alpine plant species will be pushed to local extinction once they cannot move any higher.

A warming climate in the WRR has important implications for land managers, ranchers, recreationists, wildlife, and biodiversity in general. From melting glaciers to increased disease and insect epidemics, and from greater wildfire risk to shifting plant species distributions, the WRR faces an uncertain future—one that may change the character of the Range for centuries to come.

Natural History

Dry mid-elevation sedimentary mountains (17m)

The Foothill Shrublands and Low Mountains Subsection (18d) occur near Ed Young Mountain, an upthrust limestone block composed of Madison Limestone and Bighorn Dolomite in the southeastern portion of the study area (Figure 3). Subsection 18d also occurs near Timbertop, an upthrust block of the Phosphoria, Tensleep, and Amsden Formations, in the east-central portion of the study area. Subsection 18d will be treated in the Natural History section of this manuscript along with Subsection 17 m due to the similar geology, plant communities, and climate, and relatively low areal extent (Table 1).

The topography and vegetation of the Dry Mid-Elevation Sedimentary Mountains is strongly influenced by the geologic setting of the eastern flank of the WRR, the orientation of the Wind River Fault to the northeast, and the physical characteristics of the geologic formations (Figure 15). The Flathead Sandstone dips consistently (15–25% slope) to the northeast and is divided by stream erosion into a series of crescent shaped summits abutting the Precambrian rocks of the central core of the WRR. Exposures of the Flathead sandstone may also be found along the lower reaches of the canyons created by the larger streams that dissect the eastern flank of the WRR, including Squaw, Sawmill, Canyon Creeks, and the Little Popo Agie River. Forming a steep (20–50%), scarp slope directly east of the Flathead Sandstone, the less resistant Gros Ventre Formation has eroded into a sequence of rounded summits deeply divided by stream erosion. Aspect on the Gros Ventre slopes ranges between north-northwest and south-southwest, with the summits facing westerly.

Figure 15—Panorama looking northwest from Freak Mountain—Flathead Sandstone (far left), Gros Ventre Shale (center left), Gallatin Limestone (center right), and Bighorn Dolomite (far right); southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

Atop the Gros Ventre slopes, a relatively thin layer of Gallatin Limestone creates a break in slope (15–25%). Near the upper limit of the Gallatin Limestone Formation, rock outcrops form a series of moderately steep shoulders (2–4 m in height) leading to the contact with the Bighorn Dolomite. A number of small drainages, including Whiskey, Blue Holes, Red, Spring, Squaw, Elderberry, Crooked, Snow, and Cherry Creeks, begin atop the resistant Gallatin Limestone and dissect the Bighorn Dolomite and Madison Limestone into a series of cliffy summits separated by broad Y-shaped headwaters. Aspect on the Gallatin Limestone ranges between northeast-north-northwest and south-southwest on the actual outcrops (scarp slope) to northeasterly in the headwaters (dip slope). Aspect on the Bighorn Dolomite is typically northeasterly at the summits and ranges between northerly and southerly on steep slopes above drainages. Differential weathering of the various members of the Madison Limestone Group has formed a banded pattern of rock outcrop on the south-southwesterly facing scarp slope, while the northeast facing dip slope lacks the banded pattern. Similar to the Gros Ventre Formation, the Amsden Formation is characterized by a sequence of smaller north-northwest and south-southwest facing rounded summits occurring atop the Madison Limestone. Lastly, the Tensleep Sandstone occurs in conjunction with the Amsden Formation as a series of north to east facing, triangle-shaped summits.

The Dry Mid-Elevation Sedimentary Mountains exhibit a striking vegetation zonation and species mix typical of the middle Rocky Mountains (Bailey 1995). A Rocky Mountain Douglas-fir/limber pine zone occupies lower elevation slopes, the former typically inhabiting sheltered north-facing slope positions, especially at lower elevations. Limber pine forests commonly occur along with mountain big sagebrush and Idaho fescue-bluebunch wheatgrass grasslands as a mosaic on more exposed slope positions. A spruce-fir zone occurs at higher elevations and in areas experiencing cold air drainage. Lodgepole pine is seral to subalpine fir and Rocky Mountain Douglas-fir on highly productive sites, and develops into climax stands on unproductive sites, especially on the Flathead and Tensleep Sandstone Formations.

Ponderosa pine and curl-leaf mountain mahogany, common in the Bighorn Mountains to the northeast, are notably and conspicuously absent along the eastern flank of the WRR (Little 1976; Norris and others 2006; USGS 1999). Lastly, Wyoming three-tip sagebrush, a dwarf sagebrush species typical of dry, windy sites, is unique on the Shoshone National Forest to the eastern slope of WRR (Houston and others 2001). In the Dry Mid-Elevation Sedimentary Mountains, Wyoming, three-tip sagebrush occurs on steep upper backslopes and shoulders near the contact between the Gros Ventre and Gallatin Formations.

The soils in the Dry Mid-Elevation Sedimentary Mountains Ecoregion are strongly influenced by parent material and vegetation. Flathead Sandstone typically weathers into rocky, coarse-textured, red to pink Haplocryalfs. E-horizons were commonly observed in soils derived from Flathead Sandstone, indicating the eluviation of clay minerals to lower in the soil profile. A layer of sandy-shale typically occurs near the contact with the Gros Ventre Formation. Soils formed from this sandy-shale were generally Inceptisols and weakly developed Alfisols with brown to yellowish colors, relatively low rock fragments, and low clay.

On Gros Ventre slopes, in sagebrush and grassland communites, in deep, mixed calcareous colluvium, Typic Calciustolls and Typic Calcicryolls form on south- and north-facing slopes, respectively. Soil colors vary from dark brown to black mollic colors in the surface horizons to tan and gray in the subsurface horizons. Where primary or secondary parent materials included either the Wolsey or Park Shales of the Gros Ventre Formation, clay-rich Mollisols, including Typic Argiustolls, Typic Calciustolls, and Pachic Calcicryolls, were the result. Soil colors varied from dark brown to black mollic colors in the surface horizons to greenish and yellowish in the subsurface horizons (Figure 16).

Carbonate-rich Alfisols predominated in forested communities on north-facing shale and limestone slopes in deep calcareous colluvium. Calcic Haplustalfs were typical

Figure 16—Greenish-yellow soil formed from Gros Ventre Shale, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

Figure 17—Reddish Amsden Siltstone soil with bright white Ranchester Limestone cobbles, southeast Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

of Douglas-fir communities, while Eutric Haplocryalfs characterized subalpine fir communities. Weak Alfisols and Inceptisols were more common on steeper (>40%) slopes, including Inceptic Haplocryalfs, Typic Calciustepts, and Typic Eutrocryepts.

On south-facing slopes, atop Gallatin Limestone outcrops, Alfisols and clay-rich Mollisols, including Argiustolls and Haplustalfs, occurred below the Bighorn Dolomite cliffs. Where the Bighorn Dolomite is absent, shallow to moderately deep calcareous soils reside on the Gallatin Limestone outcrops, including Lithic Calciustolls, Lithic Haplustolls, and Typic Calciustolls.

Limber pine woodlands and sagebrush/grassland communities on south-facing Bighorn Dolomite and Madison Limestone slopes were characterized by deep Typic Calciustolls and Pachic Haplustolls on back-slope and foot-slope positions. On summit and shoulder positions, the soils tended to be shallower and less developed, forming moderately deep Typic Calciustepts.

Calcareous, clay rich Mollisols predominated in the sagebrush and grassland communities associated with the Amsden Formation. Soils weathered from the Horseshoe Shale member of the Amsden Formation, formed bright red to orange, clay-rich (>20% clay) Typic Argiustolls (Figure 17). Carbonates were often present in the Horseshoe Shale soils due to the influence of colluvial Ranchester Limestone. Soils weathered from the Ranchester Limestone member of the Amsden Formation were typically dark brown to gray, sandy (<20% clay), gravelly Typic Argiustolls and Typic Calciustolls. Argiudolls were common in quaking aspen communities at toe-slope positions and other areas of concave topographic relief. Lastly, Tensleep Sandstone soils were typically coarse-textured, rocky, and little developed, including Dystrustepts and Ustorthents.

Granitic subalpine zone (17k)

The granitic subalpine zone includes the area of exposed Precambrian granitic core below timberline (~3,200 m). The landscape is dominated by steep, glacially carved U-shaped valleys flanked by deposits of deep glacial till; mountains scoured by glaciers into subdued, gently rounded slopes and summits; and thousands of glacial lakes stippling the landscape. The granitic subalpine zone culminates just downstream from glacial cirques occurring at the head of 10 major glacial valleys across the study area (from north to south): Jakeys Fork, Torrey Creek, Dinwoody Creek, Dry Creek, the North and Middle Forks of Bull Lake Creek, the South Fork Little Wind River, the North and Middle Forks of the Popo Agie, and the Little Popo Agie River.

Glacial activity was relatively low in the extreme southeastern portion of the granitic subalpine zone, including the South Pass Granite-Greenstone Belt, and in the areas to the southwest, south, and east of Louis Lake. The lack of significant glaciation in these areas is reflected in the landscape. The broad glacial valleys, typical of the majority of the granitic subalpine zone, are replaced by narrow headwaters, and a series of diabasic gabbro dikes dissects the landscape, forming a distinct trellis drainage pattern. To the west, the Continental Divide in this area drops in elevation below timberline, and a series of forested mountain peaks occurs in the granitic subalpine zone, including Granite, Pabst, and Rennecker Peaks. To the east, the Round Top Mountain Greenstone forms Round Top Mountain and the ridge that runs southwest from its summit, while the core of Iron Mountain is formed from the Iron Formation Member of the Goldman Meadows Formation. The gneiss belt and the Diamond Springs Formation have weathered into a series of rounded summits, narrow ridges, and broad, gently sloped hills.

The vegetation in the granitic subalpine zone generally resembles that of other granitic subalpine areas in Wyoming, including the Bighorn Mountains (Despain 1973), the Medicine Bow Mountains (Oosting and Reed 1952), and the Teton Range (Whitlock 1993), with broad areas of subalpine forest (Reed 1976) and whitebark pine-Idaho fescue parkland (Lynch 1988). Subalpine fir forests are limited to cooler, moister north- and east-facing slopes and cold air drainages at lower elevations in residual soils, while whitebark pine-Idaho fescue parkland commonly occurs on south- and west-facing slopes. At lower elevations, in soils derived from granitic glacial till, lodgepole pine may form persistent stands, and subalpine fir is restricted to cooler microsites. At higher elevations on granitic glacial till, whitebark pine forests dominate on south-facing slopes, and subalpine fir forests dominate on north-facing slopes; however, the influence of slope aspect is less apparent at these cooler, higher elevations. Open canopied whitebark pine forests predominate near timberline. At timberline, subalpine fir, Engelmann spruce, and whitebark pine battered by strong winds, blowing snow and ice, and bitter cold feature a shrub-like growth-form termed krummholz. Krummholz communities occur at timberline as scattered patches interspersed with alpine meadow communities. Engelmann spruce commonly co-dominates subalpine fir and whitebark pine forests along the eastern slope of the WRR; however, pure Engelmann spruce forests are not as widespread in the WRR as in other granitic subalpine areas in Wyoming. Engelmann spruce forests do occur, but they are typically limited to smaller stands on moist sites in areas with gentle topography. Near South Pass, mountain big sagebrush-Idaho fescue grasslands occur on convex slope positions, while subalpine fir and lodgepole pine forests occupy more sheltered sites. On the series of diabasic gabbro dikes that occur to the south of Louis Lake, Wyoming three-tip sagebrush-Idaho fescue communities occur on south- and west-facing shoulders and summits, while whitebark pine and subalpine fir forests occupy the north-facing slopes on upper and lower slope positions, respectively. Broad wetlands and moist meadows dominated by willows, sedges, and mesic grasses are common in the broad glacial valleys of the granitic subalpine zone.

Soils in the granitic subalpine zone tend to be less well developed, sandier, and more acidic than soils derived from fine-grained, calcareous sedimentary parent materials. The actual rock type, including granodiorite, porphyritic quartz monzonite, gneiss, or migmatite, appears to be less important than the type of parent material, including residuum, colluvium, or glacial till. Soils derived from residuum occur most often on shoulders, summits, and low gradient (<30%) backslopes. Residual soils are typically shallow to moderately deep to bedrock and feature a layer of partially decomposed bedrock, or grus, beginning around 50 to 60 cm below the soil surface. Soils located on the series of diabasic gabbro dikes that occur to the south of Louis Lake tend to have higher base saturation as a result of the high concentrations of cations (Ca^{2+}, Mg^{2+}) in the diabasic gabbro. Soils on the dikes tend to be Mollisols and Inceptisols with high base saturation, including Typic Eutrocryepts. Mollisols, including Entic Haplustolls, Lithic Argiustolls, and Lithic Haplocrolls, occur in sagebrush and grassland communities on south-facing slopes. Entisols, including Lithic and Typic Cryorthents, and Inceptisols, including Typic Eutrocryepts and Lithic and Typic Dystrocryepts, are typical of whitebark pine and subalpine fir communities on north-facing slopes.

Soils derived from colluvium are moderately deep to deep and occur most often on footslopes and steep (>30%) backslopes. In general, colluvial soils tend to be deeper and more developed than residual soils, including Inceptisols, Alfisols, and Mollisols. Mollisols, including Entic Haplustolls, Pachic Haplocryolls, Pachic Haplustolls, and Typic Argicryolls occur in sagebrush, grassland, and quaking aspen communities. Inceptisols, including Typic Eutrocryepts, Humic, and Typic Dystrocryepts, and Alfisols, including Typic, Eutric, and Inceptic Haplocryalfs, are common in subalpine fir and whitebark pine communities.

Soils derived from glacial till are typically deep. The degree of soil development in till soils is largely related to the age of the till. Soils derived from till deposited during older glaciations, including the Bull Lake and earlier, have had more time to develop than soils derived from till deposited during younger glaciations, including Pinedale and more recent. Soils in older till tend to be Alfisols, including Eutric Glossocryalfs and Inceptic Haplocryalfs, while those in younger till tend to be Inceptisols and Entisols, including Typic Cryorthents, Typic Dystrocryepts, and Humic and Typic Eutrocryepts. Densic horizons develop from the compaction of soils by glacial ice and are common in soils derived from glacial till. Vegetation on till soils is mostly forested, with lodgepole pine at lower elevations and subalpine fir and whitebark pine at higher elevation.

Alpine zone (17h)

Glaciers and glacial cirques; precipitous mountain summits; and broad, flat, high-level erosion surface remnants; craggy escarpments; and narrow ridges dominate the landscape in the Alpine Zone. The majority of the Alpine Zone includes the area of exposed Precambrian granitic core above timberline (~3,200 m). However, Paleozoic sedimentary formations, including the Flathead, Gros Ventre, Gallatin, Bighorn, and Madison, extend above timberline at Arrow, Whiskey, and Shale Mountains in the northern study area. The Continental Divide, beginning just south of Atlantic Peak and continuing northwest to Union Peak (approximately 120 km), forms the main, continuous body of the Alpine Zone. High-level erosion surface remnants, including Ram Flat, Goat Flat, Horse Ridge, Dry Creek Ridge, and Mount Hooker compose large areas of the Alpine Zone near the Continental Divide, while a number of summits located to the east of the Continental Divide, including Whiskey Mountain, Torrey Peak, Arrow Mountain, Mount Chevo, Mount Arter, and Cony Mountain represent isolated "islands" of the Alpine Zone separated from the Continental Divide by broad areas of the Granitic Subalpine Zone.

The Alpine Zone is home to the greatest number of high peaks in Wyoming. Of the 26 peaks in Wyoming with summits greater than 4,000 m (and a rise of 150 m from any saddle connecting them to a higher peak), 23 are in the WRR (Kelsey 1988). Gannett Peak in the northern WRR, at 4,207 m, is the highest peak in Wyoming. Fremont Peak just to the south of Gannett, with its impressive headwall and fluted buttresses, is the second highest peak in the WRR at 4,191 m, followed by Mount Warren (4,184 m), Mount Helen (4,152 m), and Mount Turret (4,146 m). The gently sloping summit of Wind River Peak stands at 4,022 m, making it the 15th highest peak in the WRR, and the highest peak in the southern portion of the range. Dozens of alpine glacial cirques with their sheer headwalls, including Atlantic Canyon, Silas Canyon, Stough Lakes Basin, Ice Lakes, Cirque of the Towers, South Fork Lakes, and Brown Cliffs mark the upper terminus of once extensive mountain glaciers. The WRR is also refuge to 24 intact glaciers, remnants of the last ice age, 13 of which occur on the northeastern slope. Of those, the five largest occur near Gannett Peak, and the ridge between Mount Helen and Fremont Peak: Dinwoody, Gannett, Sacagawea, Upper Fremont, and Bull Lake Glaciers.

The vegetation of the Alpine Zone is characteristic of alpine tundra vegetation of the central and southern Rocky Mountains. Vast expanses of alpine turf and fellfield vegetation dominated by Ross' avens and blackroot sedge occur on exposed mountain slopes and the plateau-like high-level erosion surface remnants. Fellfields occur on rocky, exposed sites that experience very little snow accumulation and are characterized by scattered, diminutive shrubs, forbs, and cushion plants, including Ross' avens, Hooker's mountain avens, phlox, moss campion, dwarf clover, and twinflower sandwort, grown in a matrix of erosion pavement or talus. Erosion pavement refers to a soil surface that is covered by rock fragments as the result of wind deflation—the removal of the fine-earth fraction (<2 mm) of a soil by the force of wind (Livingstone and Warren 1996; Seppälä 2004). Alpine turf occurs on less rocky, slightly more sheltered sites that experience low to moderate amounts of snow accumulation. Alpine turf vegetation is characterized by dense colonies of sod-forming sedges, including blackroot and Bellardi bog sedge, arctic and snow willows, and an array of forbs and graminoids, including Ross' avens, alpine sagebrush, moss campion, manyray goldenrod, purple reedgrass, and arctic bluegrass. On leeward slopes where deep snows accumulate, the vegetation is relatively lush compared to fellfields and turf communities due to a combination of factors, including insulation from extreme winter temperatures; protection from strong, desiccating winter winds; and increased soil moisture as a result of gradually melting snow throughout the summer months. Vegetation on leeward slopes includes grayleaf willow, tufted hairgrass, Holm's Rocky Mountain sedge, and Parry's rush.

The soils in the Alpine Zone are strongly influenced by the forces associated with seasonal and diurnal freeze-thaw cycles. Soil water expands when it freezes, thus applying a force to soil particles and rock fragments. Given enough time, this process, termed "cryoturbation," sorts rock fragments by size, shifting or heaving rocks upward in the soil profile in proportion to their size (Davis 2001). Through this differential sorting process, larger rocks are moved higher in the soil profile more quickly than smaller rocks leading to a variety of sorted ground, including stone nets and stone stripes. Stone nets occur on flat or gentle slopes (<7%), and feature a series of rock polygons, or "cells" of the "net," interlaced with a net-like pattern of smaller rock fragments and soil material (Richmond 1949). Gravity induces a linear component to the sorting process on steeper slopes (7–27%) leading to sorted stone stripes (Figure 18). At sites featuring a seasonally high water table, cryoturbation results in a number of unsorted frost features, including frost hummocks and frost boils on flat sites and solufluction landforms on sloping sites (Johnson and Billings 1962). Frost hummocks are low (typically <1 m) soil mounds that are formed from frost heaving, or the uplifting of the ground surface resulting from the freezing of water within the soil (Peterson and Krantz 2003). Frost boils are bare soil patches containing mostly silt and clay that form when the fine-grained soil particles are saturated to liquefaction, or the point where the soil particles begin to behave as a liquid and boil up through the surface due to the stress imparted by the weight of overlying soil material (Davis 2001). Liquefaction of soils on a slope can cause mass movements of soil downhill, a process termed "solufluction" (Johnson and Billings 1962). The accumulation of

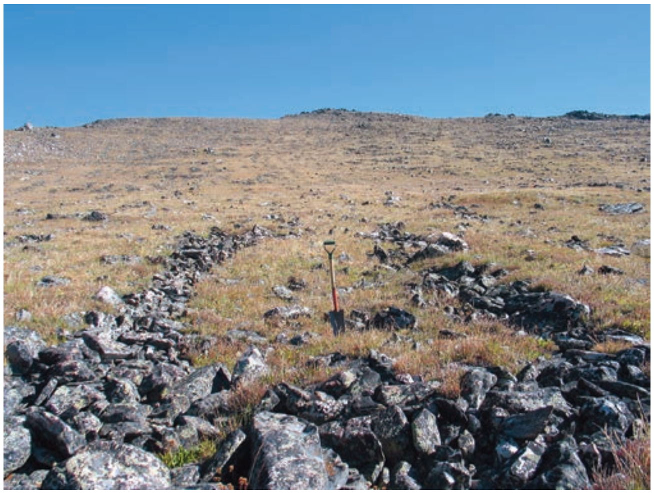


Figure 18—Sorted stone stripes on Peak 11595 above Burro Flat in the notheastern Wind River Range, Shoshone National Forest, Wyoming. Photo by Aaron Wells.

sediments from solufluction results in the burial of downhill soils and the development of distinctive landforms. Solufluction terraces are broad, bench-like landforms resulting from the accumulation of soils due to solufluction that tend to develop on shallow slopes (Davis 2001). Solufluction lobes are narrow, linear landforms resulting from the accumulation of soils due to solufluction that tend to develop on steep slopes. Cryogenic solufluction refers to solufluction caused by freeze-thaw processes. Water freezing in the interstitial spaces between soil particles results in an upward force that moves the particles in a direction perpendicular to the slope. When these same soil particles thaw, they drop straight down to a point on the slope slightly downhill from where they were originally. Repeated freeze-thaw cycles result in the slow creep of soils downhill. Cryogenic solufluction may also result in the genesis of solufluction terraces and lobes. Since adequate soil moisture is key to the solufluction process, solufluction landforms most commonly occur downhill from late melting snow banks and other areas of high soil moisture. Soils in the Alpine Zone are typically deep, loamy-skeletal Haplocryalfs in turf communities and Humic Dystrocryepts in fellfields. Turf and fellfield soils are often associated with stone stripes. Soils on leeward slopes and other areas associated with snow accumulation are typically saturated early on in the growing season and include moderately deep and deep, loamy-skeletal Oxyaquic Dystrocryepts, and sandy-skeletal Oxyaquic Cryorthents.

Factors of Soil Formation

The soils of the eastern slope of the WRR reflect the complex interactions between the five soil-forming factors of Jenny (1994), including climate, organisms, topography, parent material, and time. The composition of the parent material influences the ratio of sand, silt, and clay, which, in turn, affects the available water holding capacity of a soil (Saxton and others 1986). Chemical properties of the parent material can affect rates of weathering, carbonate content, pH, cation exchange capacity, availability of nutrients to plants, and formation and flocculation of clay minerals (Birkeland 1999). The physical and chemical properties of a soil in turn influence the vegetation species composition (i.e., organisms) of the plant communities associated with a given soil.

Slope gradient affects soil stability and thus the amount of time a soil has to develop (Berry 1987). Topographic position greatly influences the dominant geomorphic processes, erosion, or sediment accumulation, which, in turn, determines the type (residuum, colluvium, or alluvium) of parent material at a site and the thickness of the regolith. Topo-climatic gradients, created by differences in slope aspect, influence precipitation, temperature, and solar radiation patterns and significantly influence the amount of soil water available during the growing season, which, in turn, influences the vegetative potential of a site. Simultaneously, the soils are influenced by the vegetation communities and indirectly follow the topo-climatic gradients that are a major determinant of the vegetation. Soil temperature and water availability also affect the rates of chemical and physical weathering of parent material and, ultimately, the rate and degree of soil development (Tonkin and Basher 1990; Birkeland and others 2003).

Glacial till provides an excellent example of the influence of time on soil development. For instance, soils formed from Bull Lake till in the WRR, deposited some 200 to 130 Ka, have had a relatively long time to develop compared to soils derived from younger deposits. Dahms (2004b) found that soils on Bull Lake moraines in Sink Canyon had thicker surficial horizons (A- and B-), more deeply colored B-horizons, higher illuvial clay, and generally finer soil textures than soils derived from younger till deposits. Soil derived from Pinedale age glacial till, deposited approximately 22,000 to 15,000 years ago, have had relatively little time to develop compared to soils derived from older glacial till deposits. Dahms (2004b) found that soils on Pinedale moraines in Sink Canyon had the thinnest surficial horizons (A- and B-), minimal amounts of illuvial clay, and were generally the least developed soils in Sinks Canyon.

Plants influence soil temperature, texture, and pH through the input of organic matter, including leaves and fine roots, and shading of the soil surface. Plant roots affect the rate of chemical and physical weathering through root exudates and the shattering of bedrock. Thick organic horizons at the surface of forested soils and shading of the soil surface from the tree canopies above insulate the soil from drastic temperature fluctuations and maintain cooler, moister soils in forested communities than in grassland and sagebrush communities. Fine-root turnover in grassland and sagebrush communities perpetuates the development of thick, organic rich A-horizons, which encourages the continuity of non-forested communities. The type and quality of organic input into soils can impact soil pH and, ultimately, the availability of nutrients to plants. For instance, conifers concentrate acidic chemicals in their needles, which fall to the soil surface and decompose, thus lowering the pH of soils in conifer forests. On the other hand, quaking aspen leaves, which have high concentrations of cations and acid buffering qualities and that decompose quickly due to a low carbon to nitrogen ratio, provide a ready source of organic carbon and raise the pH of soils (Pylypec and Redmann 1984; Cryer and Murray 1992; Howard 1996; Legare and others 2005).

Vegetation succession following wildfire in conifer forests significantly influences the genesis of soils through time and exemplifies the parallel relationship between soils and vegetation. Following wildfire in conifer forests, vegetation is typically characterized by high abundance of quaking aspen, a common early seral species in the study area. Soils in younger stands dominated by quaking aspen typically feature thick, dark, carbon-rich surface horizons (Cryer and Murray 1992). As stand age progresses and conifer species begin to dominate the stand, herbaceous species and quaking aspen gradually decline in abundance as the forest canopy begins to close. During this time, the carbon-rich surface horizons begin to lose organic matter and thickness with reduced leaf fall. This results in increased water percolation and heightened rates of nutrient and organic matter leaching. In mature conifer forests, herbaceous species and quaking aspen are nearly absent, and the soils eventually lose all evidence of the once thick, dark surface horizons.

Methods

Field Protocols

Overview

Field sampling took place during the summers of 2004 and 2005. A preliminary map (pre-map) of soil map units (see below) was used to develop a directed, stratified, gradient-oreinted (Austin and Heyligers 1989) sampling design. The areal extent of each pre-map unit, and the study area as a whole were calculated in a GIS environment (ESRI® ArcMap™ 8.7). The percentage of the area of each map unit relative to the area of the entire study area was calculated and used as a rough guide to the relative distribution of sample points across map units. Within each map unit, sample points were chosen systematically to represent the landscape as a whole, focusing on stratification of sample points across geologic units, topographic positions, and vegetation communities (Soil Survey Division Staff 1993). Field researchers traveled to the location of each preliminary sample point (±100 m). Sample points were situated in such a way as to be entirely located in the vegetation community most representative of the landform of interest, avoiding ecotones and highly disturbed vegetation. Plots were 0.04 ha (0.1 acre) in size and circular. Along riparian areas and on other small, irregularly shaped landforms/plant communities, the shape of the plot was flexible (so long as the size remained 0.04 ha), in order that the entire plot would fit within the landform/plant community of interest. Prior to the 2005 field season, data from the first summer's sampling effort were evaluated both statistically and spatially (see "Office Protocols" section), and preliminary results were obtained. The results were examined to determine existing gaps in the data and were used to aid in stratification of sampling points for the 2005 field season. In total, 251 plots were sampled during the 2004 and 2005 field seasons (Figure 2). An additional 30 field plots from a previous study conducted in 1997 were included in the dataset for analysis and ecological type development. Data on the general site, forest inventory, vegetation composition, and soils were collected at each plot using the methods described below.

Site

Universal Transverse Mercator (UTM) coordinates were obtained for each site by using a global positioning system (GPS) (North American Datum 27, Zone 12). Photographs, including landscape and ground cover view, were taken from the plot center of each sample site, and the compass directions in which each photo was taken were recorded. Detailed site descriptions were recorded at each site, including elevation,% slope, slope aspect (compass declination set at 12° east), slope position, and slope shape. Landform and bedrock geology were noted at each site. Lastly, detailed descriptions of the sites were recorded, including general observations, disturbance history, insects and disease, indications of wildlife and human use, and geomorphic processes active at the site.

Forest inventory

Basal area tallies of tree species were obtained at forested sites (tree cover >10%) using a 10 BAF (Basal Area Factor) prism and a variable size circular plot design. The species and diameter at breast height (DBH) were recorded for each tree identified in the basal area tallies. Site trees were defined as healthy individuals representative of the size and age class of the principal tree species in the stand. A single site tree was selected for each of the principal species in a stand, and height, diameter, age (using increment borer), and DBH were recorded.

Vegetation composition

Vegetation sampling protocols followed the methodology described in Appendix C of Winthers and others (2005). Canopy cover within the sample plot for all vascular plants was estimated in increments of 1%, 3%, 5%, and 10%, and every 5% thereafter. Canopy cover of tree species was split based on overstory layer into dominant, subdominant, understory (DBH >13 cm), and seedling (DBH <2.5 cm). Percent ground cover of surface features, including submergence, bare ground, exposed bedrock, gravels, cobbles, stones, boulders, litter, wood, moss and lichen, and basal vegetation, were recorded using the same method. Potential natural vegetation was classified into habitat types (sensu

Daubenmire 1952) according to Steele and others (1983) for forested vegetation, Tweit and Houston (1980) for shrubland and grassland vegetation, and Walford and others (2001) for riparian and wetland vegetation. Since no formal alpine vegetation classification exists for the study area, alpine vegetation was classified as described in the "Ecological Type Classification" section.

Plant taxonomy: Plant taxonomy follows Dorn (2001) with the exception of *Osmorhiza purpurea* and *Poa curtifolia* following Hitchcock and Cronquist (1973), *Minuartia macrantha* and *Sedum rosea* following Scott (1995), and *Festuca viviparoidea* ssp. *krajinae* following Massatti and Wells (2008). In the study area, *Pseudotsuga menziesii* (Mirbel) Franco is variety *glauca* (Beissn.) Franco, or Rocky Mountain Douglas-fir, and may be referred to by either "Douglas-fir" or "Rocky Mountain Douglas-fir." *Pinus contorta* Dougl. ex Loud is variety *latifolia* Engelm. ex S. Wats. in the study area and is referred to as simply "lodgepole pine."

Most plant identification was conducted by the field researchers; for particularly difficult identifications, specimens were sent to an expert at the Montana State University Herbarium in Bozeman, Montana. All taxa were identified to the lowest possible taxonomic level. Plant codes follow the USDA Plants Database (USDA NRCS 2007b) with the exception of the following taxa that are accepted by Dorn (2001) but were not present in the USDA Plants Database as of analysis of these data: *Boechera* spp. Löve & Löve and *Boechera holboellii* (Hornem.) Löve & Löve. For the purposes of this discussion, the species were assigned local six-letter codes: BOECH and BOEHOL, respectively. Appendix 2 provides a list of all plant species encountered during field sampling, including USDA Plants code, Latin name, common name, and author. Voucher specimens are being stored at the USDA Forest Service, Shoshone National Forest Supervisors Office in Cody, Wyoming.

Soils

Soil sampling conformed to National Cooperative Soil Survey Protocols (Soil Survey Division Staff 1993). Soil classification follows the ninth edition of the "Keys to Soil Taxonomy" (Soil Survey Staff 2003). Soil pits were excavated by hand to a depth of just over 1 m or until contact with lithic materials or interlocking stones and boulders. Soil temperature was collected at a depth of 50 cm. Root restricting depth, drainage class, surface runoff class, and soil moisture and temperature regimes were recorded. Soil horizons were identified, and thickness (cm) of each were recorded. Dry and moist color, soil texture, structure, consistence,% coarse fragments, effervescence class, and quantity and size of roots and pores were recorded for each horizon. The location and amount of clay films, amount and color of redoximorphic features, and depth to water table were recorded when appropriate. Soil pH for each horizon was obtained using field indicators. Photographs were taken of the face of the soil pit, including an overview photo and close-up views of the upper and lower halves of the pit face. Soil samples from each horizon were collected in quart-sized zippered freezer bags. Soil samples were used to fill box samples for long-term documentation of the soils and to analyze base saturation and particle size on soils from selected horizons. Box samples of typical pedons are being stored at the Shoshone National Forest Supervisors office in Cody, Wyoming, while all other box samples are being stored with Dr. Janis Boettinger in the Plant, Soils, and Climate Department at Utah State University in Logan, Utah.

Office Protocols

Mapping

Soil mapping for the northern Shoshone National Forest was completed prior to the initiation of the present study. Within the study area, geographic information systems (GIS) and remotely sensed data were employed to create a pre-map of the soil map units before field work began following Terrestrial Ecological Unit Inventory protocols for delineating pre-map units (Winthers and others 2005). When delineating pre-map units, the focus was on dividing the landscape based on bedrock and surficial geology, topography, and broad-scale vegetation patterns. Final soil map units were mapped as complexes of two or more dissimilar soils that could not be differentiated at the scale of mapping. The study area was split based on soil survey order. All areas outside wilderness boundaries were mapped as third order, while wilderness areas were mapped as fourth order (Soil Survey Division Staff 1993). Third order map units were delineated at a mapping scale of 1:24,000 with a minimum delineation of approximately 1.5 ha. Fourth order map units were delineated at a mapping scale of 1:63,360 with a minimum delineation of approximately 5 ha. Exceptions were map units 302, 302L, and IH2O, which were mapped at at 1:24,000 and a minimum delination of 1 ha, and GLAC and W, which were mapped at 1:10,000 and a minimum delineation of 0.5 and 0.25 ha, respectively.

Soil map units from the northern Shoshone National Forest extend into the study area along the northern boundary of the northern study area. Where sufficient field data existed, the delineations of these northern Shoshone National Forest map units were reworked and these polygons were assigned the appropriate soil map unit code (including associated soil map unit components and Ecological Types) from the study area. Soil map unit delineations and associated soil map components were left unchanged, and Ecological Types were not assigned where field data was insufficient to verify changes to the northern Shoshone National Forest map units. Exact joins were completed on final soil map unit lines to ajoining soil surveys, including Fremont County, Wyoming, East Part and Dubois Area (Survey Area WY713) and Bridger National Forest, Wyoming, Eastern Part (WY662). As per NCSS protocols, soil map units from these adjoining surveys were shared across survey area boundaries where appropriate.

Data management

Overview

Vegetation and site data were entered into the USFS Natural Resource Information System Terra Module (NRIS Terra), which consists of an Oracle database/GIS application and set of analysis tools designed to implement corporate data standards for TEUI and Rangeland Management. Soil and site data were entered into the NRCS National Soils Information System (NASIS).

Aspect

Aspect value is a cosine transformation of aspect into solar radiation equivalents, and includes a correction of 30°, which reflects the relative heat of the atmosphere at the time the peak radiation is received (Roberts and Cooper 1989). Accordingly, the maximum value of av (1.0) occurs at 30° aspect, and the minimum value (0.0) occurs at 210° aspect. Aspect value was calculated using the following formula:

aspect value = (cos((aspect-30)/180*pi)+1)/2

Cardinal aspect direction is a categorical variable that divides aspect into 16 categories of cardinal direction. See Table 4 for aspect range within each category. Lastly,% clay and coarse fragments (>2mm) in the particle size control section and average weighted pH were calculated for each soil pedon.

Estimation of available water capacity

Available water capacity (AWC) is an estimate of the water potentially available to plants between permanent wilting point and field capacity after hydric soils have drained due to gravity, and is measured as N cm of water per one meter of soil. AWC for mineral soil horizons was obtained from the USDA Soil Conservation Service on AWC (Appendix 3).

Available water capacity for organic soil horizons was calculated by the following method. Boelter (1969) provided regression equations for calculating water content from fiber content of organic soils. Equations were provided for 0.1 bar and 15 bar suctions (permanent wilting point). No equations were provided for field capacity (0.33 bar); therefore, water content at 0.1 bar was calculated as an estimate of field capacity for organic soils. AWC at different fiber contents was estimated by calculating the water content across the full range of fiber contents for each type of organic material (fibric [67, 74, 81, 88, 95, 100%], hemic [33, 40, 47,54, 61, 66%], and sapric [1, 8, 15, 22, 29, 32%]) at both 0.1 and 15 bar suctions. The difference in water content between 0.1 and 15 bar was calculated and then averaged across the six values of fiber content. AWC estimates for sapric fiber contents were obtained by averaging the values for all six fiber contents, removing 1%, and removing 1 and 8%. The decision was made to use the results obtained by removing 1 and 8% fiber contents since such low fiber content soils are technically closer to loams and silt loams than to organic soil. The results for the AWC of organic soils calculation are presented in Table 5.

The AWC for each soil was estimated by calculating AWC for each horizon to a depth of 1 m for deep soils or to bedrock for shallow to moderately deep soils. The AWC for each horizon was calculated as follows:

Horizon thickness (cm)*AWC (cm/cm)*(1-Fraction Rock Fragments) = Horizon AWC (cm)

Total AWC for the soil pit (cmcm of water per meter of soil) was calculated by summing all horizon AWC values for a given soil to a depth of 1 m.

Climate data—modeled

Dr. Niklaus Zimmermann of the Swiss Federal Institute for Forest, Snow, and Landscape Research developed spatially explicit climate models for the entirety of the Shoshone National Forest. The result of the modeling effort was a set of GIS raster maps representing the derived climate variables. Mean annual precipitation (MAP) and mean monthly precipitation (MMP), mean monthly potential

Table 4—Aspect range (degrees) within sixteen classes of cardinal direction.

Cardinal direction	Abbreviation	Aspect range (degrees)
North	N	349–11
North-Northeast	NNE	12–33
Northeast	NE	34–56
East-Northeast	ENE	57–78
East	E	79–101
East-Southeast	ESE	102–123
Southeast	SE	124–146
South-Southeast	SSE	147–168
South	S	169–191
South-Southwest	SSW	192–213
Southwest	SW	214–236
West-Southwest	WSW	237–258
West	W	259–281
West-Northwest	WNW	282–303
Northwest	NW	304–326
North-Northwest	NNW	327–348

Table 5—Available Water Capacity (AWC) of organic soils by texture.

Texture	Available water capacity (cm water/cm soil)	Range AWC
Fibric	0.20	0.005–0.38
Hemic	0.46	0.39–0.51
Sapric	0.50	0.47–0.51

evapotranspiration (PET), daily temperature, mean annual temperature (MAT), and summer radiation (SUMRAD) were calculated following the methodology described in Edwards and others (2005). Degree days were calculated by multiplying the number of days for which the mean temperature of a pixel exceeds an arbitrary standard of 0 °C by the mean temperature over this period, while frost-free days were calculated by simply summing the number of days exceeding 0 °C on a pixel by pixel basis (Zimmermann and Roberts 2000). Zimmerman and Kienast (1999) provided a detailed description of the derivation of degree days. Lastly, site water balance was an estimate of the water available to plants during the growing season and integrated climatic and soil parameters (Zimmermann and Roberts 2000). The climate data for each sample point were obtained by spatially joining the sample point layer and each climate raster layer in a GIS.

Estimation of site water balance

Available water capacity is an estimate of the water potentially available to plants between permanent wilting point and field capacity after hydric soils have drained due to gravity, and is a function of soil texture, coarse fragment content, and soil depth. Inputs of water to the soil through precipitation and groundwater sources and loss of water due to evapotranspiration are independent of AWC. When placed in the context of the difference between precipitation and evapotranspiration, AWC provides a more meaningful estimation of the water available to plants through the growing season. Site water balance (SWB) is an estimate of the water available to plants during the growing season and integrates MMP, PET, and AWC. Beginning with the first month where MMP>PET, SWB was estimated by calculating a running sum of the difference between MMP and PET. When the running sum exceeded AWC, the difference was assumed to run off. The running sum was continued for a total of one year.

Soil temperature and moisture regimes

Soil Temperature Regime (STR) is a soil taxonomy concept that refers to the range of temperatures a soil experiences annually. Soil Moisture Regime (SMR) refers to the presence or absence of ground water or the amount of water in a given soil that is available to plants (Soil Survey Staff 2003). For a given soil, the designation of STR and SMR is based on a series of soil temperature and moisture criteria and is critical to consistent classifications of soils between adjacent soil survey areas. The soil temperature and moisture criteria are based on long-term (30 year) averages of these variables. Therefore, soil temperature and moisture data collected while describing a soil in the field, at a single point in time, are insufficient as criteria for designating STR and SMR classes. Barring long-term soil temperature and moisture data, an objective, invariable set of criteria should be chosen when designating STR and SMR for a given soil.

At the landscape scale, the soils along the eastern flank of the WRR fall within the Cryic/Frigid and Udic/Ustic soil temperature and moisture regime classes, respectively. At the community scale, distinguishing between the two sets of STR and SMR classes for a given soil required the objective, invariable set of criteria, previously discussed. Table 6 contains the list of criteria used to designate STR and SMR for soils of the eastern flank of the WRR. The criteria include known indicator species of cool/moist and warm/dry environments and topographic factors that influence solar radiation input, temperature, and moisture availability. Soils were preliminarily classified into STR and SMR classes in the field using the vegetation and topography rules listed in Table 6. Box and whisker diagrams were used to check the consistency of the vegetation and topography rules used to determine STR and SMR with the modeled climate data. Box and whisker diagrams are a simple means of displaying a range of data. The

Table 6—Vegetation and environment criteria used to designate soil temperature and soil moisture regimes.

Cryic/Udic

- Elevations > 2,750 m.
- Any or all of the following species present in the vegetation community: subalpine fir, whitebark pine, and/or lodgepole pine.
- All sample sites located on Flathead Sandstone.

Frigid/Ustic

- Elevations ≤ 2,750 m.
- Sample sites located on sedimentary bedrock (except Flathead Sandstone) AND meeting the elevation critera listed above.

Frigid/Udic

- Quaking aspen communities on sedimentary bedrock (except Flathead Sandstone).

Udic

- Sample sites with Idaho fescue in the understory at greater than or equal to 5% foliar cover.

Ustic

- Sample sites with bluebunch wheatgrass in the understory at greater than or equal to 5% foliar cover.

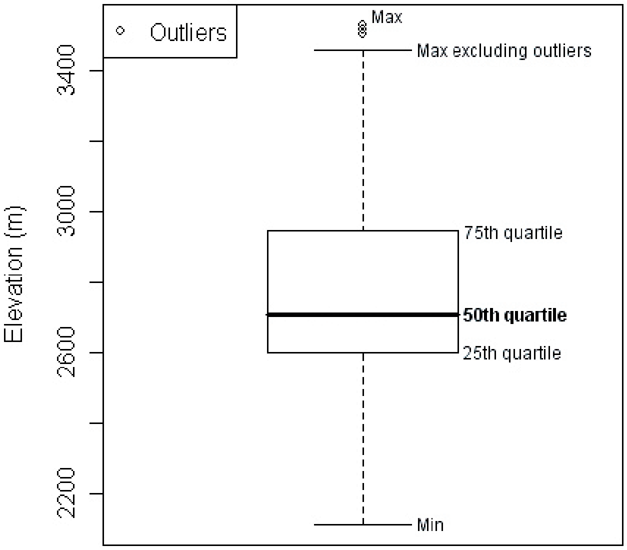


Figure 19—Example of box and whisker diagram depicting the distribution of sample points across elevation.

diagrams were plotted using the R function boxplot, while minimum, maximum, and quartiles were calculated using the summary function (R Development Core Team 2007). Box and whisker diagrams display the 50th (median), 75th, and 25th quartiles, minimum, maximum, and outliers of a distribution of values (Figure 19). Similar to percentiles, quartiles are a member of a family of statistics that divide a frequency distribution into equal areas (Sokal and Rohlf 1987). For instance, 25% of the values in a distribution lie above the 75th quartile and below the 25th quartile. The inter-quartile distance is defined as the difference between the 75th and 25th quartile and is used as a basic summary statistic for describing the central range of values in a distribution. Outliers are defined as those values in the distribution that are greater than (75th quartile+(N*(75th–25th))) and less than (25th quartile–(N*(75th–25th))). The value of N determines the sensitivity of the box and whisker plot to outliers. The lower the value of N, the more sensitive to outliers. The value of N was set at 1.5 for the purposes of this study.

Box and whisker diagram of degree days (Figure 20) and frost-free days (not shown) were plotted across all sample points within the two STR categories. Unpaired Welch's two-sample t-tests showed that across the range of variation in degree days, sample points considered Cryic based on the vegetation and environment rules had significantly ($p<0.001$) lower degree days and frost-free days than sample points considered Frigid. In order to test for consistency between the vegetation/topography rules and the climate data, all plots falling within the upper 25% of both degree days and frost-free days for plots considered Cryic, and the lower 25% of both degree days and frost-free days for Frigid were identified and further scrutinized. The 25% rule relies on the assumption that those plots considered Cryic, and that fall within the upper 25% of the data distribution, represent plots that have higher degree days and frost-free days than would be expected considering the remaining Cryic plots, while those plots considered Frigid, and that fall within the lower 25% of the data distribution, represent plots that have lower degree and frost-free days than could be expected considering the remaining Frigid plots. Although the 25% rule is somewhat arbitrary (a 20% or 15% rule could also be applied), the important point is the consistency with which the 25% rule was used. A similar analysis was conducted for SMR using annual average precipitation and SWB (data not shown). Upon further scrutiny, it was determined that the vegetation rules were consistent with the climate data in

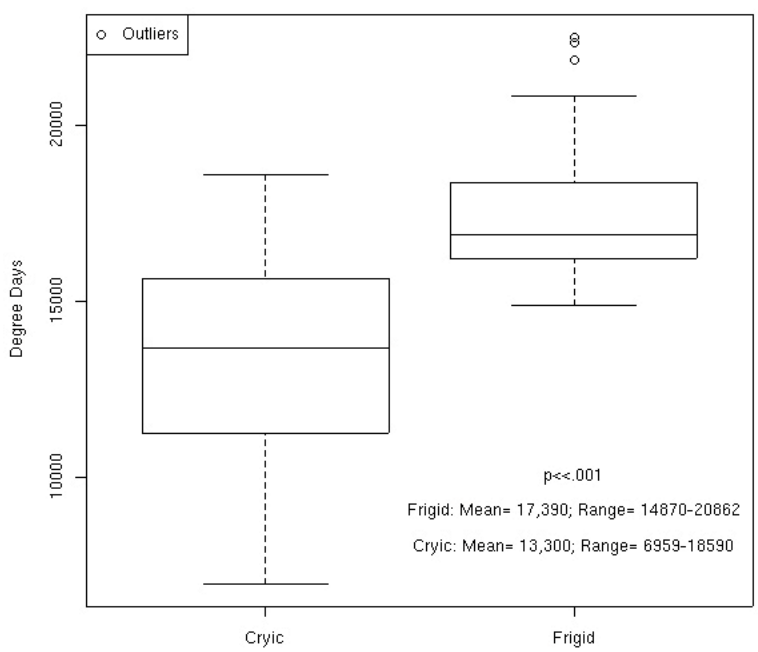


Figure 20—Box and whisker diagram depicting depicting cryic and frigid sample points across degree days.

86% of the plots. Thirty-five of the 251 plots required a change in STR and SMR, the majority of which occurred in the South Pass area and were changed from Cryic/Udic to Frigid/Ustic.

Data analysis

Overview

An ecological type is a category of land with a distinctive combination of landscape elements, including climate, bedrock geology, landform, and soils, and that differs from other types in the kind and amount of vegetation it can produce and in its ability to respond to management actions and natural disturbances (Winthers and others 2005). Ecological type classifications integrate the combination of landscape elements previously described into an ecosystem-based classification by drawing on ecological relationships. Recognizing and interpreting ecological relationships is a primary task of many ecologists. However, ecological datasets are often quite complex, including multiple dependent and independent variables that interact with one another across a number of spatial and temporal scales. Ecological data are also full of superfluous information, or noise, that can mask the relationships that scientists seek. Multivariate statistical analysis includes a suite of statistical techniques designed specifically to distill complex ecological datasets, thus enhancing the ability of the ecologist to recognize patterns within the data. Similar to a carpenter using a hammer to construct a building, the ecologist uses multivariate statistics techniques as tools to develop an ecological classification. Multivariate statistical techniques are important tools used in the classification process to draw inferences from the data and provide objective criteria for decision making. However, the skill involved in developing an ecological type classification goes beyond the actual tools used, requiring knowledge of species autecology, ecosystem processes, and classification systems. Multivariate statistical techniques, including ordination and Generalized Additive Models, were used in part to develop the ecological type classification presented in this management guide.

Preliminary data analysis

All statistical analyses were conducted in R: a language and environment for statistical computing (R Development Core Team 2007, http://www.r-project.org). The vegetation and environment data were initially separated by sample plot into pre-map unit vegetation and environment datasets by grouping them based on the pre-map unit in which the sample plots were located. Following the 2004 field season, basic summary tables were constructed that summarized the number of sample plots within each pre-map unit. The number of sample points per pre-map unit was compared to the relative distribution of sample points across pre-map units calculated during the initial phase of sampling design. This provided a rough estimate of the number of sample points in each pre-map unit remaining to be sampled during the upcoming 2005 field season.

Box and whisker diagrams were employed in the preliminary data analysis to compare the ranges of sampled percent slope and elevation (“sampled”) to the ranges of percent slope and elevation that occurred within each pre-map unit (“extent”). The first step was to calculate a raster layer of percent slope across the study area using a 10-m Digital Elevation Model (DEM). The DEM and the percent slope raster were converted to a point layer using the “Convert Raster to Features” tool in the Spatial Analyst extension of ArcMap 9.1. The DEM and the percent slope layers, each composed of a grid of points occurring where the center of each pixel was located in the raster, were then spatially joined to the pre-map polygon layer using the “Join Data” tool in ESRI® ArcMap™ 8.7. During the join, each of the points in the DEM and percent slope layers were given the attributes of the pre-map unit polygon in which they were located. These data represented the extent of elevation and slope within each pre-map unit. Box and whisker diagrams were plotted and summary statistics were calculated for sampled and extent elevation and slope within each pre-map unit dataset. The distribution of sampled and extent elevation and slope within each pre-map unit were visually compared with one another. If the range of the sampled variable was skewed above the mean of the extent, then higher values of the variable were over-sampled in that pre-map unit, and the 2005 sampling scheme was adjusted to focus on sampling lower values of the variable. If the range of the sampled variable was skewed below the mean of the extent, then lower values were over-sampled, and the 2005 sampling scheme was adjusted to focus on sampling higher values of the variable within that pre-map unit. An objective criterion for determining a significant difference between sampled and extent follows. Calculate the mean and standard deviation for the extent of the variable within each pre-map unit. Next, calculate the mean of the variable for the sample points within each pre-map unit. If the mean of the sampled points falls outside ± one-half standard deviation of the mean of extent of elevation or slope, this represents a gap in the survey data for that variable within a given pre-map unit.

Ordination is a multivariate statistical technique that displays the projection of a multidimensional point cloud in two dimensions. Ordination utilizes the compositional similarity, or the inverse, dissimilarity, between sample points in ecological community datasets to arrange the sample points in multidimensional ordination space. Similarity, in the case of sample points in a study of ecological communities, is related to the presence and absence of species. Sample points with many species in common are more similar than sample points with little or no species in common. In this way, sample points similar in species composition appear closer together in the ordination space, while dissimilar points appear further apart.

For each pre-map unit vegetation dataset, a Bray/Curtis (Bray and Curtis 1957) dissimilarity matrix was calculated from the raw canopy coverage data using the R function dsvdis (Roberts 2006). The dissimilarity matrix was used to calculate three-dimensional non-metric multidimensional scaling (NMDS) ordinations (Kruskal 1964a, 1964b; Shepard 1962a, 1962b) using the R function nmds (Roberts 2006). The ordinations were plotted in all three sets ([1,2], [1,3], [2,3]) of dimensions. The ordination diagrams were initially inspected for outliers, or those sample points more similar in vegetation composition to themselves than to any other sample point. Outliers were usually located well outside the primary point cloud. Outliers within pre-map unit datasets suggested three situations: (1) the vegetation type was more extensive within a pre-map unit but was not sampled adequately, (2) the vegetation type was rare and truly represented an outlier, and (3) that the sample site may have fit better in another pre-map unit and the polygon lines in the pre-map required adjustment. Outliers were noted, and an attempt was made during the 2005 field season to more adequately sample the vegetation types represented by outliers.

Ecological relationships were examined and preliminary map unit components were identified by testing the orientation of sample points along the ordination axes relative to a number of environmental factors. A minimum of three sample points was used to define major soil components (see "Classification Concepts" section). Preliminary major map unit components included groups of three or more habitat types with similar soils and environment within each pre-map unit. Also, potential major soil map unit components were identified as individual sample points or in groups less than three of similar habitat types/great groups within each map unit. The researcher noted these and made an attempt during the following field season to validate the potential major soil map unit components by sampling or observing more of these in the field.

Categorical environmental variables, including vegetation series, slope position, soil depth, soil parent material, soil classification, habitat type, and bedrock geology, were symbolized on the ordination diagrams using the R function points (R Development Core Team 2007). The categorical variables were tested for their degree of deviation from randomness along each set of ordination axes using the R function ordtest (Roberts 2006). Significant deviations from randomness suggested that the categories of the variable were more highly aggregated along the set of ordination axes than would be expected if the categories were randomly distributed across the ordination space. Categorical variables with significant deviations from randomness were considered potentially important in differentiating between map unit components and were examined more closely in the final data analysis.

Continuous environmental variables, including elevation, slope, aspect value, percentage of coarse fragments, percentage of clay, AWC, site water balance, and the modeled climate variables, were evaluated using the R function surf (Roberts 2006). The function surf first fits a Generalized Additive Model (GAM) (Hastie and Tibshirani 1986; Yee and Mitchell 1991) using the R function gam (Wood 2006) to the ordination axes for each continuous environmental variable. The function surf next plots a modeled surface, similar to lines on a topographic map, that represents the predicted distribution of the environmental variable across the ordination space. The fit value for a GAM is deviance squared (D^2), and is equivalent to R^2 in least squared regression (Guisan and Zimmerman 2000). The higher the fit value, the better the GAM fits the actual distribution of the environmental variable along the ordination axes, and (indirectly) the greater the importance of that variable in structuring the vegetation composition. Continuous environmental variables with high fit values were considered potentially important in differentiating between Ecological Types and were examined more closely in the final data analysis.

Final data analysis and map unit components

Following the 2005 field season, ecological relationships were examined, outliers were identified, and final map unit components were classified following the same general methods described for the preliminary data analysis. Outliers were either removed entirely from the data or moved to a more appropriate pre-map unit. This was an iterative process by which the outliers were removed/moved and the ordinations recalculated. During the final data analysis, groups of three or more of the same or similar habitat types within each pre-map unit ordination were considered potential map unit components. The environmental variables identified in the preliminary data analysis were used to test for ecological relationships between the potential map unit components. Variables used in the analysis included vegetation series, habitat type, soil great group, soil depth, slope position, elevation, slope, site water balance, summer radiation, soil parent material, and % clay. The final map unit components were classified based on similarities in vegetation, soils, and environment. The statistical analyses were used as a guide in the classification process and provided objective criteria for deciding between splitting and lumping sample sites in the classification. The researcher also drew upon knowledge of species autecology and ecological process and observations made in the field to develop the final classification.

The classification of the forested components of map unit 12L provides a relatively simple example of the classification process. A three-dimensional NMDS ordination was plotted in dimensions one and three using the data for the forested sample points within map unit 12L. First, vegetation series was highlighted on the map unit 12L forested ordination using the R function chullord.nmds (Roberts 2006), revealing sample sites in the limber pine series on the lower end of the NMDS axis 1 and sample sites in the Rocky Mountain Douglas-fir series on the upper end of NMDS axis 1 (Figure 21). Second, soil depth was symbolized on the ordination diagram, bringing to light the relationship between soil depth and vegetation series (Figure 22). Shallow to moderately deep soils mostly occurred at points near the lower end of NMDS axis 1, corresponding in large part to the limber pine series, while

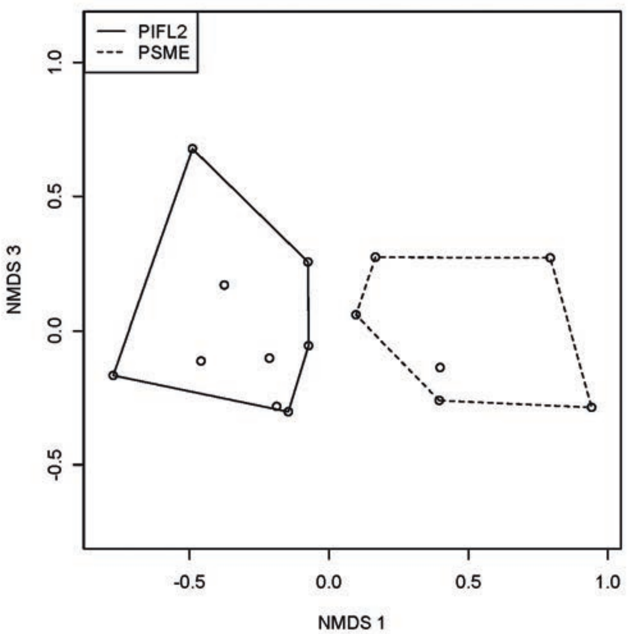


Figure 21—Non-metric multidimensional scaling (NMDS) plot of map unit 12L forested sample points with vegetation series symbolized.

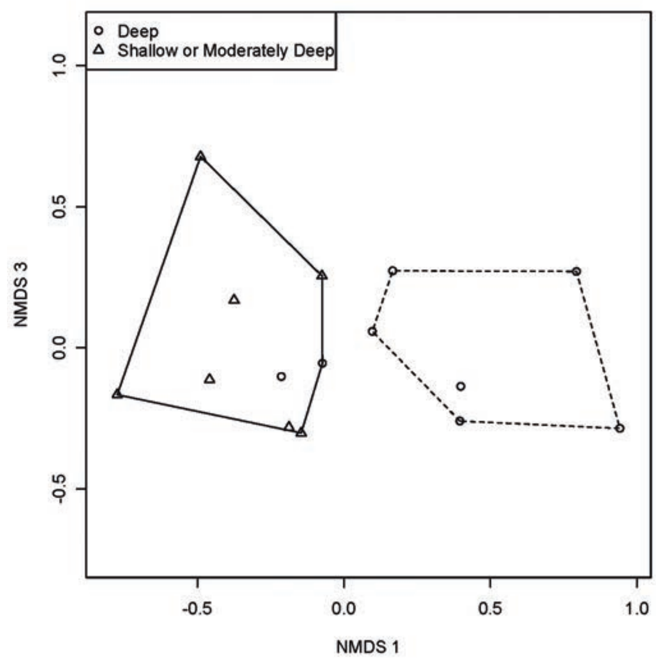


Figure 22—Non-metric multidimensional scaling (NMDS) plot of map unit 12L forested sample points with soil depth symbolized.

deep soils occurred largely on the upper end of NMDS axis 1, corresponding to the Douglas-fir series. The shallow to moderately deep soils in the limber pine series were all located at limestone shoulder and summit positions in limestone residuum. Two deep soils occurred in the limber pine series; these were located on back-slope positions in limestone colluvium. Next, soil classification was highlighted on the ordination diagram indicating that Alfisols and clay-rich Mollisols occurred almost exclusively beneath Douglas-fir communities, while clay-poor Mollisols and Inceptisols occurred beneath limber pine communities (Figure 23). The forested components of map unit 12L reflect the above patterns, and included (1) limber pine/common juniper, Lithic Calciustolls; (2) Limber pine/common juniper, deep, Pachic Haplustolls; and (3) Douglas-fir/common juniper, deep, Typic Argiustolls.

A second example demonstrates the use of GAMs and the R function ordtest in the soil map unit classification. A three-dimensional NMDS ordination was plotted in dimensions one and three using the data for the non-forested sample points in map unit 15L. First, habitat type was symbolized on the map unit 15L forested ordination using the R function points, and the habitat types with at least three sample points were highlighted using the R function chullord.nmds (Figure 24).

Ordtest revealed that the distribution of the habitat type categories in the ordination was significantly different from a random configuration ($p = 0.001$), suggesting that habitat type was an important variable in the development of the non-forest map unit components in map unit 15L. Next, a GAM of elevation was calculated and plotted using

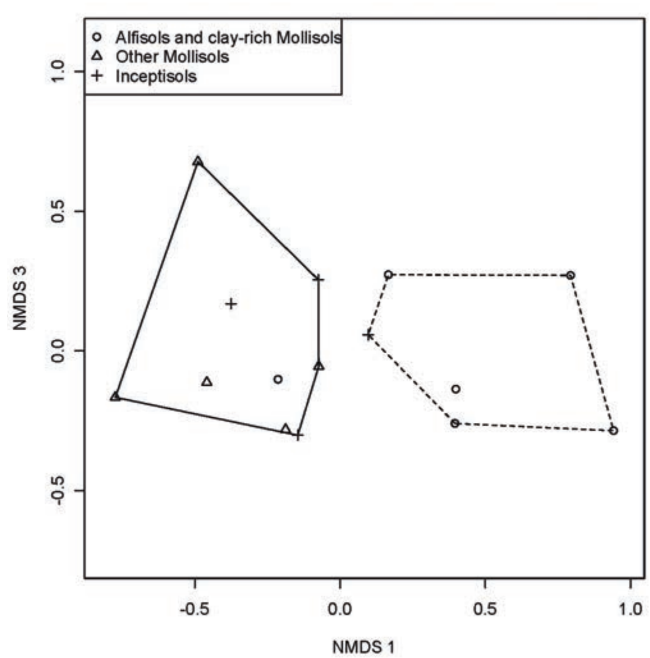


Figure 23—Non-metric multidimensional scaling (NMDS) plot of map unit 12L forested sample points with soil order symbolized.

the first and third NMDS axes (Figure 25). The model predicted ($D2 = 0.36$) higher elevations on the left end of axis 1, corresponding to the Wyoming three-tip sagebrush/bluebunch wheatgrass habitat type (ARTRR4/ ELSP3), and lower elevations on the right end of axis 1, corresponding to the mountain big sagebrush/Idaho fescue habitat

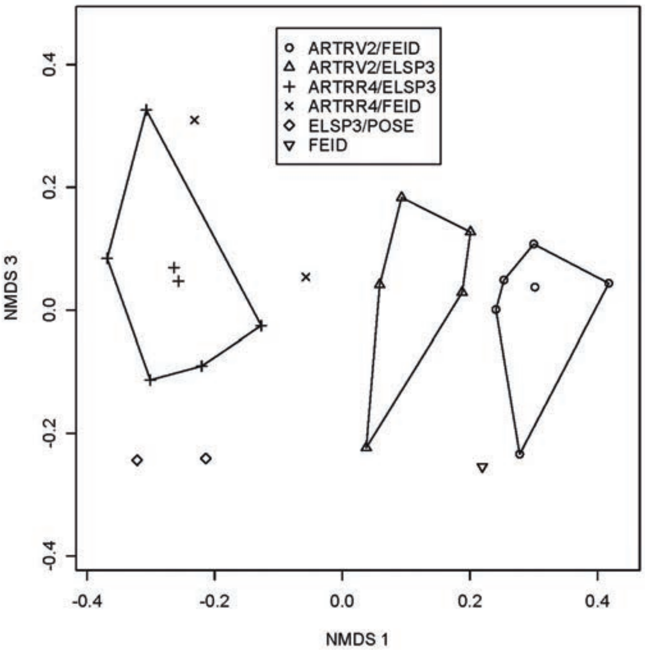


Figure 24—Non-metric multidimensional scaling (NMDS) plot of map unit 15L non-forested sample points with habitat type symbolized.

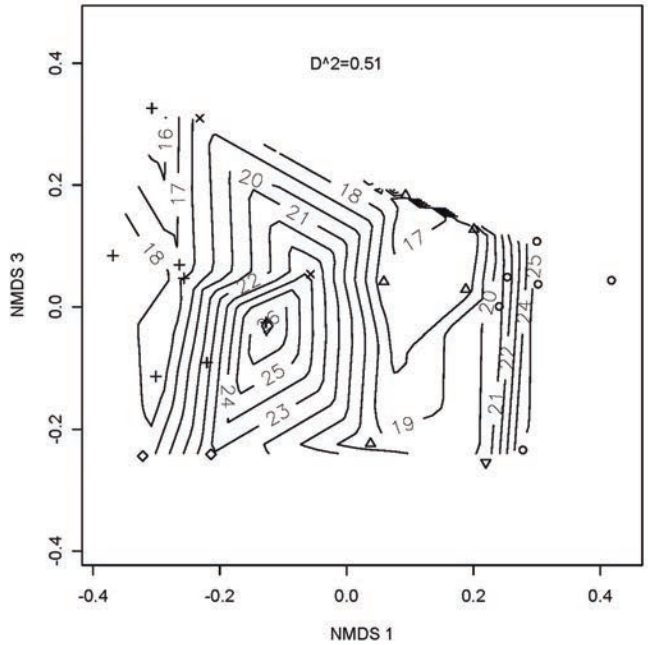


Figure 26—Non-metric multidimensional scaling (NMDS) plot of map unit 15L non-forested sample points with generalized additive model (GAM) of percent clay in the particle-size control section overlaid.

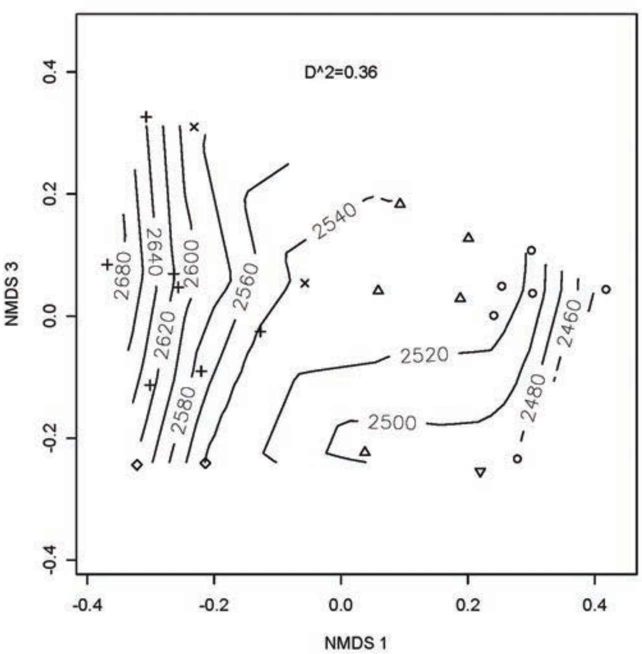


Figure 25—Non-metric Multidimensional Scaling (NMDS) plot of map unit 15L non-forested sample points with generalized additive model (GAM) of elevation overlaid.

type (ARTRV2/FEID), with the mountain big sagebrush/ bluebunch wheatgrass (ARTRV2/ELSP3) habitat type at moderate elevations. The elevation GAM fits with a general pattern observed by the field researcher in which ARTRR4/ ELSP3 was located primarily on upper backslopes and shoulder positions, ARTRV2/ELSP3 was located on middle and lower backslopes, and ARTRV2/FEID was located primarily on footslopes.

Lastly, a GAM of % clay in the particle-size control section was calculated and plotted using the first and third NMDS axes (Figure 26). The D2 of 0.51 was somewhat better than for elevation, and the model predictions were slightly more complicated. The model generally predicted increasing % clay from left to right along axis 1; however, a localized high of % clay occurred near the center of axes 1 and 3. The predicted increases in % clay corresponded to soils with argillic horizons, which occurred almost exclusively in the ARTRV2/FEID habitat type (data not shown). The major non-forested soil map unit components for 15L reflect the above patterns of habitat type, elevation, and % clay: mountain big sagebrush/Idaho fescue, deep, Typic Argiustolls; mountain big sagebrush/bluebunch wheatgrass, deep, Typic Calciustolls; and Wyoming three-tip sagebrush/ bluebunch wheatgrass, deep, Typic Calciustolls.

Results and Discussion

Soil Map Units and Ecological Types

Sixty-one map units occurred in the northern and southern study areas combined, including 34 from the Shoshone National Forest survey area (WY656), 20 pulled into the study area from the adjoining Fremont County, Wyoming, East Part and Dubois Area survey area (WY713), and 7 pulled from the ajoining Bridger National Forest, Wyoming, Eastern Part survey area (WY662) (Table A-1). The five largest map units accounted for approximately 58% of the study area and included 304L (36,371.0 Ha), 327S (26,089.4), 319L (21367.5), 311L (15187.8), and 310L (12312.3). Twenty-five map units were assigned ecotypes, including 23 from WY656 and 2 from WY713. Thirty-six map units were not assigned ecotypes, including 11 from WY656, 18 from WY713, and 7 from WY662. Figure 27 presents the soil map units in the southern study area. Complete spatial and tabular data for the entirety of the Shoshone National Forest NCSS are freely available at the NRCS Soil Data Mart at www.http://soildatamart.nrcs.usda.gov/ (USDA NRCS 2008).

A few minor disparaties existed between the ecological type classification and the soil map unit components related to differences between NCSS and TEUI protocols. These disparities are explained and a cross-reference between soil map unit components and ecotypes is presented in Appendix 4. Soil map unit descriptions and the areal extent within the study area are presented in Appendix 5.

A total of 59 ecological types were classified in the study area, including 4 alpine, 38 forested, 9 shrubland, 5 herbaceous, and 3 riparian and wetland. The remainder of this document provides the classification and description of the ecological types, including keys to the ecological types based on vegetation and environment. Ecological type descriptions are organized by vegetation physiognomy (e.g., alpine, forest, shrubland, etc.) and along an environmental gradient from the coldest/driest to the warmest/wettest ecological types.

Ecological Type Key

Overview

The Ecological Type Key is an organized means by which to identify ecological types in the field. While not technically a dichotomous key, the ecological type key is very similar, leading the user through a series of logical conditions that address both vegetation composition and environment, including soil parent material, landform, and elevation. The criteria used in the key were chosen for ease of identification in the field. Technical soil properties, including soil texture, diagnostic subsurface horizons, and soil depth, were purposefully excluded from the ecological type key as these are often difficult to determine in the field, requiring extra time to excavate a soil pit and specialized equipment and skills for proper data collection and description. As such, terminal nodes of some branches of the key may result in more than one ecological type. In these cases, the vegetation and general environment of the ecological types sharing a terminal node were very similar, and the key was not able to further differentiate between the types based on the environmental criteria used. In such cases, the user should (1) refer to the description of each of the types listed under the terminal node; (2) take note of the subtle differences in vegetation, environment, and ecology described; (3) compare the types described to the vegetation and environmental conditions at the site in question; and (4) choose the appropriate ecological type.

Using the ecological type key

If you, (1) are standing on the east slope of the WRR within the study area described above, (2) are interested in identifying an assemblage of vegetation/environment as a classified ecological type, and (3) have this guide with you, then you should begin with the Key to Ecosystems.

First, locate a relatively homogenous patch of vegetation that is obviously associated with a specific landform or slope position (see "Glossary"). An appropriate sample site should be located firmly on the landform and should not be near the boundary between two landforms. Next, go to the Key to Ecosystems and determine the ecosystem where the site is located. Plots should be roughly 390 m^2 (about 0.1 acre) in size and circular (11.3-m radius). On long, narrow landforms, such as in steep, narrow riparian zones, the shape of the plot may be changed to fit on the landform so long as the area of the plot approximates 390 m^2. Next, go to the Key to Ecological Types and select the appropriate portion of the key for a given ecosystem and work your way through.

Two options exist for highly disturbed sites that do not fit in this classification: (1) use the Ecological Type Key to match remnant patches of native vegetation (if such patches exist) as closely as possible to a classified type, and (2) use the Environment Key to determine possible vegetation potentials for the site.

Notes regarding the ecological type key

Rocky Mountain Douglas-fir and Limber Pine Series

Rocky Mountain Douglas-fir and limber pine will often be found co-dominating sites in the study area, which may cause confusion when using the Ecological Type Key to differentiate between these two vegetation series. The following suggestions are provided to help alleviate this confusion. The user is reminded that the vegetation classification is based on potential natural vegetation. As such, the Ecological Type Key relies on the criteria of a species being "present and reproducing successfully with ≥5% cover". This criteria holds up well when one species is obviously out-competing the other in the understory. However, when both species are present and reproducing successfully, this criterion becomes less effective. In the case of both species being present and reproducing successfully, the following environmental guidelines should aid in decision making: (1) Douglas-fir series on north-facing footslopes, backslopes, and shoulders below 2700 m elevation, (2) Douglas-fir series at elevations above 2700 m on south-facing Gallatin Limestone shoulders and on granitic backslopes and footslopes, (3) limber pine series on south-facing limestone, or dolomite back-slope, shoulder, and summit positions, (4) limber pine series on limestone and dolomite outcrops and on shallow to moderately deep soils.

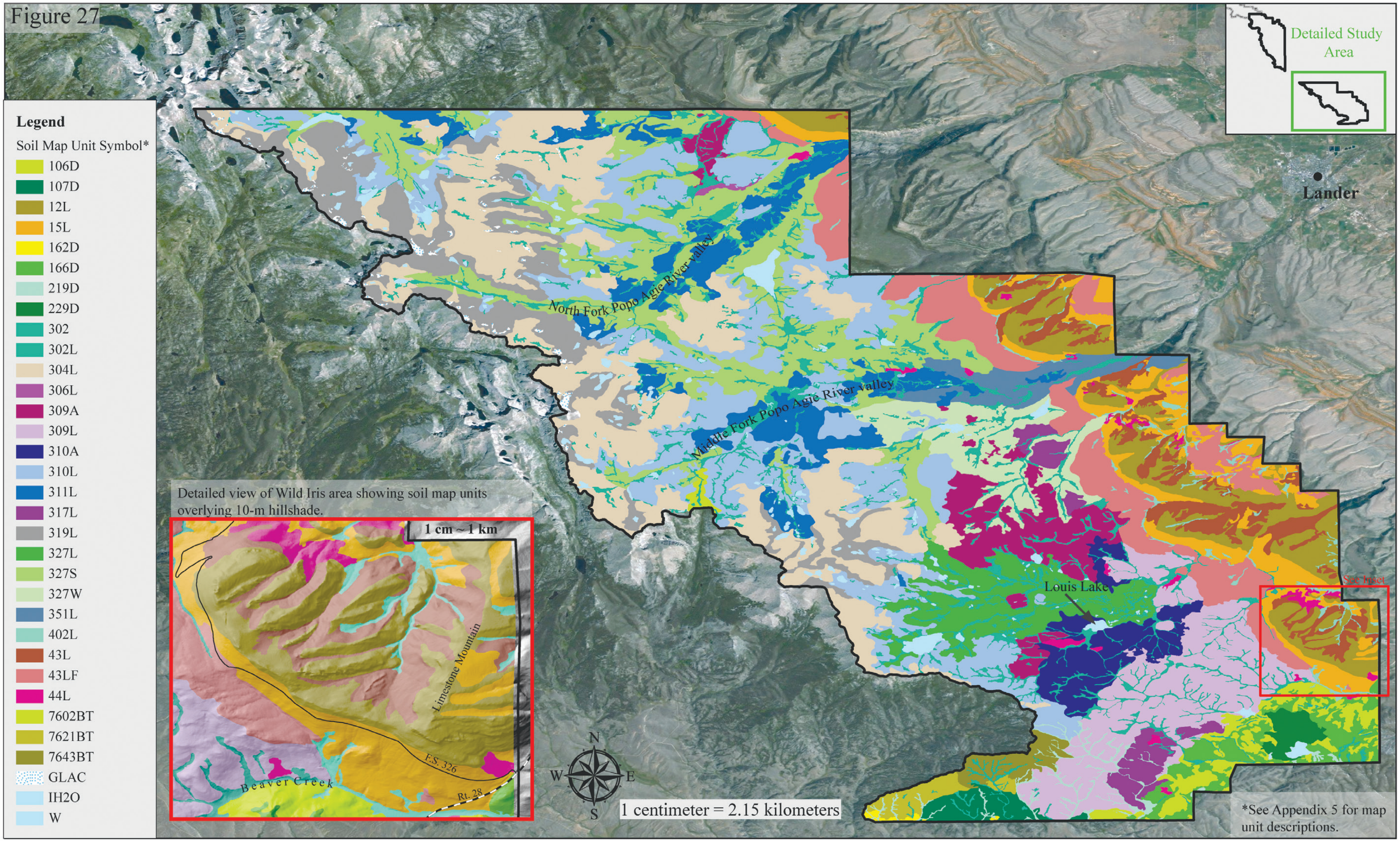


Figure 27—Soil map units (USDA NRCS 2008) in the south study area, ecological types of the eastern slope of the Wind River Range, Shoshone National Forest, Wyoming. Soil map units 1701BT and 8004BT not shown. Background imagery from ESRI ArcGIS Online and data partners (ESRI 2012).

Purpose and Limits of the Ecological Type Key

The Ecological Type Key was developed for efficient field identification of the Ecological Types described in this guide. The Key is not the classification, and users are advised to thoroughly read the description of an ecological type upon identification. The cutoff values for percentage cover in the key are general guidelines and may have no ecological basis. The user should be keenly aware of the relative importance of the indicator species present at a site and give priority to those indicator species most representative of the landform at large (most vigorous growth, not isolated to microsites, etc.).

The classification provided is not exhaustive of the possible vegetation types and environments along the eastern slope of the WRR. An effort was made to sample only relatively undisturbed sites, and the boundaries between relatively distinct vegetation types, or ecotones, were avoided. Therefore, it is possible that users of this key will encounter unclassified Ecological Types in the field. The Environment Key is provided to aid in recognition of the possible vegetation potentials at obviously disturbed sites.

Additional resources

If the Ecological Type Key fails, it may be that the vegetation type and/or environment were not sampled during the field effort, or that the vegetation type does not fit in the study area. In this case, reference the following:

Forested

Pfister, R.D.; B.L. Kovalchik; S.F. Arno; and R.C. Presby. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-GTR-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

Steel, R., R.D. Pfister, R.A. Ryker, and J.A. Kittams. 1981. Forest habitat types of central Idaho. Gen. Tech. Rep. INT-GTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 138 p.

Steele, R., S.V. Cooper, D.M. Ondov, D.W. Roberts, and R.D. Pfister. 1983. Forest habitat types of eastern Idaho-western Wyoming. Gen. Tech. Rep. INT-GTR-144. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 122 p.

Shrub and Grassland

Hironaka, M., M.A. Fosberg, and A.H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Moscow, ID: Forest, Wildlife, and Range Experiment Station, University of Idaho.

Mueggler, W.F. and W. L. Stewart. 1980.Grassland and shrubland habitat types of Western Montana. Gen. Tech. Rep. INT-GTR-66. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 154 p.

Tweit, S.J. and K.E. Houston. 1980. Grassland and shrubland habitat types of the Shoshone National Forest. Golden, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region. 143 p.

Alpine

Cooper, S.V., P. Lesica, and D. Page-Dumroese. 1997. Plant community classification for alpine vegetation on the Beaverhead National Forest, Montana. Gen. Tech. Rep. INT-GTR-362. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 61 p.

Riparian/Wetland

Walford, G., G. Jones, W. Fertig, S. Mellman-Brown, K.E. Houston. 2001. Riparian and wetland plant community types of the Shoshone National Forest. Gen. Tech. Rep. RMRS-GTR-85. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 122 p.

Youngblood, A.P.; W.G. Padgett; and A.H. Winward. 1985. Riparian community type classification of eastern Idaho-western Wyoming. R4-ECOL-85-01. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 89 p.

Miscellaneous

Jones, G. and S. Ogle. 2000. Characterization abstracts for vegetation types on the Bighorn, Medicine Bow, and Shoshone National Forests. Prepared for USDA Forest Service, Region 2. Laramie, WY: Wyoming Natural Diversity Database, University of Wyoming, Laramie. 218 p.

Key to Ecosystems

1a. Sites above timberline (ca. 3200 m); not including riparian areas and wetlands .... **I. Alpine Ecological Types**

1b. Sites at or below timberline 2

2a. Upland sites .... **II. Upland Ecological Types**

2b. Riparian and wetland sites .... **III. Riparian and Wetland Ecological Types**

Key to Ecological Types

I. Alpine Ecological Types

1a. Grayleaf willow (*Salix glauca* var. *villosa*) cover ≥ 25 percent AND sites located in late snowbank environments 2

2a. Holm's Rocky Mountain sedge (*Carex scopulorum*) cover ≥ 25 percent .... **Late snowbank vegetation -- Willow/Holm's Rocky Mountain sedge, Hargran Family ET [p. 85]**

2b. Holm's Rocky Mountain sedge cover < 25 percent 3

3a. Tufted hairgrass (*Deschampsia caespitosa*) cover ≥ 25 percent or the dominant graminoid .... **Late snowbank vegetation -- Grayleaf willow/tufted hairgrass, Hargran Family ET [p. 85]**

3b. Tufted hairgrass cover < 25 percent and not the dominant graminoid .... Undefined type or not Alpine Series

1b. Grayleaf willow cover < 25 percent OR sites other than late snowbank environments 4

4a. Snow willow (*Salix reticulata* var. *nana*) cover ≥ 5 percent 5

5a. Holm's Rocky Mountain sedge (*Carex scopulorum*) cover ≥ 25 percent AND sites located in late snowbank environments .... **Late snowbank vegetation -- Willow/Holm's Rocky Mountain sedge, Hargran Family ET [p. 85]**

5b. Holm's Rocky Mountain sedge cover < 25 percent OR sites other than late snowbank environments 6

6a. Bellardi bog sedge (*Kobresia myosuroides*) cover ≥ 15 percent or the dominant graminoid .... **Snow willow/Bellardi bog sedge, McCall Family ET [p. 81]**

6b. Bellardi bog sedge cover < 15 percent and not the dominant graminoid .... Undefined type or not Alpine Series

4b. Snow willow cover < 5 percent 7

7a. Tufted hairgrass (*Deschampsia caespitosa*) cover ≥ 25 percent or the dominant graminoid 8

8a. Sites located in late snowbank environments .... **Late snowbank vegetation -- Tufted hairgrass, Hargran Family ET [p. 85]**

8b. Other sites .... Undefined type or not Alpine Series

7b. Tufted hairgrass cover < 25 percent and not the dominant graminoid 9

9a. Parry's rush (*Juncus parryi*) cover ≥ 25 percent or the dominant graminoid 10

10a. Sites located in late snowbank environments .... **Late snowbank vegetation -- Parry's Rush, Hargran Family ET [p. 85]**

10b. Other sites .... Undefined type or not Alpine Series

9b. Parry's rush cover < 25 percent and not the dominant graminoid 11

11a. Ross' avens (*Geum rossii* var. *turbinatum*) cover ≥ 15 percent OR the dominant forb in an otherwise graminoid dominated continous turf 12

12a. Blackroot sedge (*Carex elynoides*) cover ≥ 15 percent or the dominant graminoid in an otherwise graminoid dominated continous turf .... **Ross' avens-Blackroot sedge Alpine Turf, Agneston Family ET [p. 76]**

12b. Blackroot sedge cover < 15 percent and not the dominant graminoid 13

13a. Forb dominated communities, OR graminoid dominated communities with graminoids occuring discontinuously, AND cushion plants, including dwarf clover (*Trifolium nanum*), alpine clover (*T. dasyphyllum*), phlox (*Phlox* spp.), twinflower sandwort (*Minuartia obtusiloba*), and moss campion (*Silene acaulis* var. *subacaulescens*), occuring at ≥ 5 percent cover either singly or collectively .... **Ross' avens Alpine Fellfield, McCall Family ET [p. 72]**

13b. Vegetation not as above .... Undefined type or not Alpine series

11b. Ross' avens cover < 15 percent and not the dominant forb .... Undefined type or not Alpine series

II. Upland Ecological Types

Lifeform Key

1a. Greater than or equal to 10 percent tree cover .... **A. Upland Forested Ecological Types**

1b. Less than 10 percent tree cover 2

2a. Greater than or equal to 10 percent shrub cover .... **B. Upland Shrubland Ecological Types**

2b. Less than or equal to 10 percent shrub cover .... **C. Upland Grassland Ecological Types**

A. Key to Upland Forested Ecological Types

1a. Subalpine fir (*Abies lasiocarpa*) **present and reproducing successfully with cover ≥ 5 percent** .... **Subalpine fir Series [2]**

2a. Grouse whortleberry (*Vaccinium scoparium*) cover ≥ 5 percent 3

3a. Soils derived from granitic glacial till on upper elevation (>2800 m) lateral moraines
.... **Subalpine fir/grouse whortleberry, McCall Family ET [p. 100]**
.... **Subalpine fir/grouse whortleberry, Swapps Family ET [p. 131]**

3b. Soils derived from sandstone or granitic colluvium and residuum 4

4a. Soils derived from sandstone colluvium and residuum
.... **Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]**

4b. Soils derived from granitic colluvium and residuum
.... **Subalpine fir/grouse whortleberry, Elting Family ET [p. 105]**
.... **Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]**

4c. Other soils .... Undefined type or not subalpine fir series

2b. Grouse whortleberry cover < 5 percent 5

5a. Oregon grape (*Mahonia repens*) cover ≥ 1 percent or Oregon boxleaf (*Pachistima myrsinites*) cover ≥ 5 percent
.... 6

6a. Soils derived from limestone and/or dolomite colluvium
.... **Subalpine fir/Oregon grape, Frisco Family ET [p. 120]**

6b. Soils derived from granodiorite colluvium and residuum .... **Warm subalpine fir forests, Elting Family ET [p. 115]**

6c. Other soils .... Undefined type or not subalpine fir series

5b. Oregon grape cover < 1 percent and Oregon boxleaf cover < 5 percent 7

7a. Gooseberry currant (*Ribes montigenum*) cover ≥ 5 percent or the dominant plant of normally depauperate undergrowths 8

8a. Whitebark pine (*Pinus albicaulis*) cover ≥ 5 percent and sites located at or near treeline (ca. 3200 m) and communities occurring as "tree islands" .... **Subalpine fir/gooseberry currant, Elting Family ET [p. 95]**

8b. Whitebark pine cover < 5 percent and sites located below treeline (2900-3100 m) and communities occurring as contiguous forest
.... **Subalpine fir/gooseberry currant, Cranbay Family ET [p. 131]**

8c. Whitebark pine cover ≥ 5 percent or not, sites not as above .... Undefined type or not subalpine fir series

7b. Gooseberry currant cover < 5 percent and not the dominant plant of normally depauperate undergrowths 9

9a. Common juniper (*Juniperus communis*) cover ≥ 5 percent 10

10a. Soils derived from sandstone colluvium and residuum .... **Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]**

10b. Soils derived from granodiorite colluvium and residuum .... **Warm subalpine fir forests, Elting Family ET [p. 115]**
Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]

10c. Other soils .... Undefined type or not subalpine fir series

9b. Common juniper cover < 5 percent 11

11a. Heartleaf arnica (*Arnica cordifolia*) cover ≥ 5 percent or the dominant undergrowth species 12

12a. Soils derived from igneous colluvium and residuum .... **Warm subalpine fir forests, Elting Family ET [p. 115]**
Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]

12b. Soils derived from sedimentary colluvium and residuum 13

13a. Soils derived from limestone and/or dolomite colluvium over limestone, dolomite, or sandstone residuum and sites located in cold air drainages .... **Subalpine fir/heartleaf arnica - Cold Air Drainage, Hierro Family ET [p. 125]**

13b. Soils derived from sandstone colluvium over sandstone or sandy-shale residuum .... **Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]**

13c. Soils and/or sites not as above .... Undefined type or not subalpine fir series

12c. Other soils .... Undefined type or not subalpine fir series

11b. Heartleaf arnica cover < 5 percent and not the dominant undergrowth species .... Depauperate or undefined type or not subalpine fir/upland series

1b. Subalpine fir cover < 5 percent and/or not reproducing successfully 14

14a. Engelmann spruce (*Picea engelmannii*) **present and reproducing successfully with cover ≥ 5 percent** .... please refer to "Engelmann spruce Series" in Steele and others 1983 [p. 16] for a key to the Engelmann spruce Habitat Types

14b. Engelmann spruce cover < 5 percent 15

15a. Whitebark pine (*Pinus albicaulis*) present and reproducing successfully with cover ≥ 5 percent .... **Whitebark pine series [16]**

16a. Whitebark pine and other tree species with a "flagged" or "krummholz" growth form, sites at or slightly above timberline .... **Krummholz, Klootch Family ET [p. 136]**

16b. Whitebark pine featuring a "spire" growth form, sites below timberline 17

17a. Grouse whortleberry (*Vaccinium scoparium*) cover ≥ 5 percent 18

18a. Soils derived from granitic glacial till 19

19a. Sites located on the upper extent of the Louis Lake moraine (ca. west of Louis Lake Loop Road) or on lower elevation (< 3000 m) lateral moraines near Worthen Meadows or near the headwaters of Sawmill Creek .... **Whitebark pine/grouse whortleberry, Salt Chuck Family ET [p. 145]**

19b. Sites located on upper elevation (≥ 3000 m) lateral moraines or on ground moraines in glacial cirques .... **Whitebark pine/grouse whortleberry, Jeru Family ET [p. 140]**

19c. Other sites .... Undefined type or not whitebark pine series

18b. Other soils 20

20a. Soils derived from sandstone colluvium over sandstone residuum .... **Whitebark pine Series, Marosa Family ET [p. 159]**

20b. Soils derived from granitic colluvium and/or residuum
.... **Whitebark pine/grouse whortleberry, Jeru Family ET [p. 140]**
.... **Whitebark pine/grouse whortleberry, Elting Family ET [p. 158]**
.... **Whitebark pine/grouse whortleberry, Sig Family ET [p. 158]**

20c. Other soils .... Undefined type or not whitebark pine series

17b. Grouse whortleberry cover < 5 percent 21

21a. Common juniper (*Juniperus communis*), russet buffaloberry (*Shepherdia canadensis*), or timber milkvetch (*Astragalus miser*) cover ≥ 5 percent or dominant either singly or collectively 22

22a. Soils derived from sandstone colluvium over sandstone residuum

.... **Whitebark pine Series, Marosa Family ET [p. 159]**

22b. Soils derived from granitic colluvium and/or residuum .... **Whitebark pine/Ross' sedge, Como Family ET [p. 153]**

22c. Other soils .... Undefined type or not whitebark pine series

21b. Common juniper, russet buffaloberry, and timber milkvetch cover < 5 percent and not dominant either singly or collectively 23

23a. Ross' sedge (*Carex rossii*) present and the dominant graminoid 24

24a. Soils derived from granitic colluvium and/or residuum
.... **Whitebark pine/Ross' sedge, Como Family ET [p. 153]**
.... **Whitebark pine/Ross' sedge, Frisco Family ET [p. 149]**

24b. Other soils .... Undefined type or not whitebark pine series

23b. Ross' sedge absent or not dominant graminoid .... Depauperate or undefined type or not whitebark pine/upland series

15b. Whitebark pine cover < 5 percent and/or not reproducing successfully 25

25a. Douglas-fir (*Pseudotsuga menziesii*) present and reproducing successfully with cover ≥ 5 percent .... **Douglas-fir Series [26]**

26a. Soils derived from limestone and/or dolomite colluvium 27

27a. Rocky Mountain maple (*Acer glabrum*) cover ≥ 5 percent 28

28a. Soils derived from limestone and/or dolomite colluvium over limestone, dolomite, or sandstone residuum .... **Douglas-fir/Rocky Mountain maple, Redfist Family ET [p. 161]**

28b. Soils derived from limestone and/or dolomite colluvium over granitic glacial till .... **Douglas-fir/Rocky Mountan maple, Yourame Family ET [p. 178]**

27b. Rocky Mountain maple cover < 5 percent 29

29a. Oregon grape (*Mahonia repens*) or Oregon boxleaf (*Pachistima myrsinities*) cover ≥ 5 percent either singly or collectively .... **Douglas-fir/Oregon grape, Cloud Peak Family ET [p. 167]**

29b. Vegetation not as above 30

30a. Common juniper (*Juniperus communis*) cover ≥ 5 percent .... **Douglas-fir/common juniper, Shawmut Family ET [p. 172]**

30b. Common juniper cover < 5 percent 31

31a. Utah snowberry (*Symphoricarpos oreophilus* var. *utahensis*), black chokecherry (*Prunus virginiana* var. *melanocarpa*), or whiskly currant (*Ribes cereum*) cover ≥ 5 percent .... **Douglas-fir/Utah snowberry, Typic Calciustepts ET [p. 178]**

31b. Vegetation not as above .... Undefined type or not Douglas-fir series

26b. Other soils .... Depauperate or undefined type or not Douglas-fir/upland series

25b. Douglas-fir cover < 5 percent and/or not reproducing successfully 32

32a. Limber pine (*Pinus flexilis*) **present and reproducing successfully with cover ≥ 5 percent** .... **Limber pine series [33]**

33a. Common juniper (*Juniperus communis*) cover ≥ 5 percent 34

34a. Soils derived from calcareous sedimentary colluvium and/or residuum
.... **Limber pine/common juniper, Lolo Family ET [p. 181]**
.... **Limber pine/common juniper, Tyzak Family ET [p. 187]**

34b. Soils derived from granodiorite colluvium over residuum .... **Limber pine/common juniper, Como Family ET [p. 197]**

34c. Other soils .... Undefined type or not limber pine series

33b. Common juniper cover < 5 percent 35

35a. Spike fescue (*Leucopoa kingii*) present and more abundant than Idaho fescue (*Festuca idahoensis*) 36

36a. Sites located on limestone or dolomite shoulder and summits AND soils derived from limestone or dolomite residuum .... **Limber pine/common juniper, Lolo Family ET [p. 181]**

36b. Sites located on Gros Ventre Shale backslopes AND soils derived from mixed limestone and dolomite colluvium .... **Limber pine/spike fescue, Saddlehorse Family ET [p. 192]**

36c. Other sites or soils .... Undefined type or not limber pine series

35b. Spike fescue absent or less abundant than Idaho fescue .... Depauperate or undefined type or not limber pine/upland series

32b. Limber pine cover < 5 percent and/or not reproducing successfully 37

37a. **Lodgepole pine** (*Pinus contorta* var. *latifolia*) **present and reproducing successfully with cover ≥ 5 percent** .... **Lodgepole pine Series [38]**

38a. Grouse whortleberry (*Vaccinium scoparium*) cover ≥ 5 percent 39

39a. Soils derived from sandstone .... **Lodgepole pine/grouse whortleberry, Telcher Family ET [p. 231]**

39b. Other soils .... Undefined type or not lodgepole pine series

38b. Grouse whortleberry cover < 5 percent 40

40a. Oregon grape (*Mahonia repens*) or Oregon boxleaf (*Pachistima myrsinites*) cover ≥ 5 percent 41

41a. Sites located on the lower extent of the Louis Lake moraine unit (ca. east of Louis Lake Loop Road) .... **Lodgepole pine/common juniper, Holland Lake Family ET [p. 206]**

41b. Sites located in the South Pass Granite-Greenstone Belt .... **Lodgepole pine Series, Corbly Family ET [p. 226]**

41c. Sites located on lower backslope or footslope positions on Flathead Sandstone Formation .... **Lodgepole pine/Oregon grape, Agneston Family ET [p. 201]**

41d. Sites not as above .... Undefined type or not lodgepole pine series

40b. Oregon grape (*Mahonia repens*) and Oregon boxleaf (*Pachistima myrsinites*) cover < 5 percent 42

42a. Common juniper (*Juniperus communis*) cover ≥ 5 percent 43

43a. Sites located on the lower extent of the Louis Lake moraine unit (ca. east of Louis Lake Loop Road) .... **Lodgepole pine/common juniper, Holland Lake Family ET [p. 206]**

43b. Sites located on upper backslopes and shoulder on Flathead or Tensleep Sandstone Formations .... **Lodgepole pine/heartleaf arnica, Como Family ET [p. 216]**

43c. Sites located on lower backslope or footslope positions on Flathead Sandstone Formation .... **Lodgepole pine/Oregon grape, Agneston Family ET [p. 201]**

43d. Sites not as above .... Undefined type or not lodgepole pine series

42b. Common juniper cover < 5 percent 44

44a. Russet buffaloberry (*Shepherdia canadensis*) cover ≥ 5 percent 45

45a. Sites located on the lower extent of the Louis Lake moraine (ca. east of Louis Lake Loop Road) .... **Lodgepole pine/common juniper, Holland Lake Family ET [p. 206]**

45b. Sites located on lower elevation (< 3000 m) lateral moraines near Worthen Meadows, Frye Lake, and along Burnt Gulch and Sawmill Creeks .... **Lodgepole pine/russet buffaloberry, Bohica Family ET [p. 211]**

45c. Sites located in the South Pass Granite-Greenstone Belt .... **Lodgepole pine Series, Corbly Family ET [p. 226]**

45d. Sites not as above .... Undefined type or not lodgepole pine series

44b. Russet buffaloberry cover < 5 percent 46

46a. Heartleaf arnica (*Arnica cordifolia*) or timber milkvetch (*Astragalus miser*) cover ≥ 5 percent 47

47a. Sites located on upper backslopes and shoulder on Flathead or Tensleep Sandstone Formations .... **Lodgepole pine/heartleaf arnica, Como Family ET [p. 216]**

47b. Sites located in the South Pass Granite-Greenstone Belt .... **Lodgepole pine Series, Corbly Family ET [p. 226]**

47c. Sites not as above .... Undefined type or not lodgepole pine series

46b. Heartleaf arnica and timber milkvetch cover < 5 percent 48

48a. Ross' sedge (*Carex rossii*) cover ≥ 5 percent or the dominant undergrowth species 49

49a. Sites located on lower elevation (< 3000 m) lateral moraines near Worthen Meadows, Frye Lake, and along Burnt Gulch and Sawmill Creeks .... **Lodgepole pine/russet buffaloberry, Bohica Family ET [p. 211]**

49b. Sites located on upper backslopes and shoulders on Flathead or Tensleep Sandstone Formations .... **Lodgepole pine/heartleaf arnica, Como Family ET [p. 216]**

49c. Sites located in the South Pass Granite-Greenstone Belt .... **Lodgepole pine Series, Corbly Family ET [p. 226]**

49d. Sites located on shoulders and summits of outcrops of foliated Louis Lake granodiorite just west of the South Pass Granite-Greenstone Belt .... **Lodgepole pine/Ross' sedge, Stecum Family ET [p. 231]**

49e. Other sites with soils formed from igneous or metamorphic residuum and/or colluvium .... **Lodgepole pine/Ross' sedge, Targhee Family ET [p. 221]**

49f. Sites not as above .... Undefined type or not lodgepole pine series

48b. Ross' sedge cover < 5 percent .... Depauperate or undefined type or not lodgepole pine/upland series

37b. Lodgepole pine cover < 5 percent and/or not reproducing successfully 50

50a. Quaking aspen (*Populus tremuloides*) present and reproducing successfully with cover ≥ 5 percent .... Quaking aspen Series [51]

51a. Toeslopes along the periphery of conifer forests or topographic depressions; soils derived from sedimentary rocks 52

52a. Sticky purple geranium (*Geranium viscosissimum*) and/or starry false lily of the valley (*Maianthemum stellatum*) cover ≥ 1 percent .... **Quaking aspen/sticky purple geranium, Bullflat Family ET [p. 235]**

52b. Sticky purple geranium and starry false lily of the valley cover < 1 percent .... Undefined type or not quaking aspen series

51b. Sites not as above 53

53a. Granitic boulder-strewn backslopes and footslopes 54

54a. Utah snowberry (*Symphoricarpos oreophilus* var. *utahensis*) cover ≥ 5 percent .... **Quaking aspen/Utah snowberry - Boulder, Ledgefork Family ET [p. 240]**

54b. Utah snowberry < 5 percent .... Undefined type or not quaking aspen series

53b. Sites not as above .... Depauperate or undefined type or not quaking aspen/upland series

50b. Quaking aspen cover < 5 percent and/or not reproducing successfully .... Depauperate or undefined type or not forested/upland series

B. Key to Upland Shrubland Ecological Types

1a. Wyoming three-tip sagebrush (*Artemisia tripartita* var. *rupicola*) cover ≥ 10 percent or the dominant sagebrush species .... Wyoming three-tip sagebrush Series [2]

2a. Idaho fescue (*Festuca idahoensis*) cover ≥ 5 percent 3

3a. Sites located on a series of intrusive dikes to the south and east of Louis Lake; soils derived from granodiorite and/or diabasic gabbro .... **Wyoming three-tip sagebrush/Idaho fescue, Ledgefork Family ET [p. 248]**

3b. Other soils .... Undefined type or not Wyoming three-tip sagebrush series

2b. Idaho fescue cover < 5 percent 4

4a. Bluebunch wheatgrass (*Elymus spicatus*) cover ≥ 5 percent 5

5a. Soils derived from mixed limestone and dolomite colluvium AND sites located on steep upper backslopes and shoulder near the boundary between the Gros Ventre and Gallatin limestone formations .... **Wyoming three-tip sagebrush/bluebunch wheatgrass, Bigsheep Family ET [p. 252]**

5b. Other sites or soils .... Undefined type or not Wyoming three-tip sagebrush series

4b. Bluebunch wheatgrass cover < 5 percent .... Depauperate or undefined type or not Wyoming three-tip sagebrush

1b. Wyoming three-tip sagebrush cover < 10 percent and not the dominant sagebrush species 6

6a. Low sagebrush (*Artemisia arbuscula*) cover ≥ 10 percent or the dominant sagebrush species .... Low sagebrush Series [7]

7a. Idaho fescue (*Festuca idahoensis*) cover ≥ 5 percent
.... **Low sagebrush/Idaho fescue Habitat Type [please refer to Tweit and Houston (1980) for a description of this habitat type]**

7b. Idaho fescue cover < 5 percent .... Depauperate or undefined type or not low sagebrush series

6b. Low sagebrush cover < 10 percent 8

8a. Mountain big sagebrush (*Artemisia tridentata* var. *vaseyana*) cover ≥ 10 percent or the dominant sagebrush species
.... **Mountain big sagebrush series [9]**

9a. Idaho fescue (*Festuca idahoensis*) cover ≥ 5 percent 10

10a. Sites located in the South Pass Granite-Greenstone Belt
.... **Mountain big sagebrush/Idaho fescue, Corbly 166D Family ET [p. 266]**
.... **Mountain big sagebrush/Idaho fescue, Lithic Argiustolls ET [p. 270]**

10b. Sites located on the upper extent of the Sinks Canyon moraine along the Middle Fork Popo Agie River; soils derived from granitic glacial till .... **Mountain big sagebrush/Idaho fescue, Corbly 351L Family ET [p. 279]**

10c. Sites along footslopes of the Gros Ventre or Amsden Formations
.... **Mountain big sagebrush/Idaho fescue, Shawmut Family ET [p. 258]**
.... **Mountain big sagebrush/Idaho fescue, Kiev Family ET [p. 279]**

10d. Sites located on a series of intrusive dikes to the south and east of Louis Lake; soils derived from granodiorite and/or diabasic gabbro .... **Mountain big sagebrush/Idaho fescue, Ledgefork Family ET [p. 279]**

10e. Other sites or soils .... Undefined type or not mountain big sagebrush series

9b. Idaho fescue cover < 5 percent 11

11a. Bluebunch wheatgrass (*Elymus spicatus*) cover ≥ 5 percent 12

12a. Soils derived partly or entirely from mixed limestone and dolomite colluvium
.... **Mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET [p. 274]**

12b. Other soils .... Undefined type or not mountain big sagebrush series

11b. Bluebunch wheatgrass cover < 5 pecent .... Depauperate or undefined type or not mountain big sagebrush/shrubland series

8b. Mountain big sagebrush cover < 10 percent and not the dominant shrub .... Depauperate or undefined type or not shrubland/upland series

C. Key to Upland Grassland Ecological Types

1a. Parry's rush (*Juncus parryii*) cover ≥ 5 percent or the dominant graminoid .... Miscellaneous Graminoid Series [2]

2a. Sites located at or below timberline in granitic glacial till, soils saturated within one meter of the soil surface for a short period during the growing season often the result of late melting snowbanks .... **Parry's rush, Oxyaquic Cryorthents ET [p. 294]**

2b. Sites and soils not as above .... Undefined type or not Parry's rush series or not Upland Ecological Types

1b. Parry's rush cover < 5 percent and not the dominant graminoid .... [3]

3a. Idaho fescue (*Festuca idahoensis*) cover ≥ 5 percent or the dominant graminoid .... Idaho fescue Series [4]

4a. Columbia needlegrass (*Achnatherum nelsonii*) and/or red avens (*Geum triflorum*) cover ≥ 1 percent 5

5a. Soils derived from granitic residuum .... **Idaho fescue-bluebunch wheatgrass-Columbia needlegrass, Elwood Family ET [p. 284]**

5b. Soils not as above .... Undefined type or not Idaho fescue series

4b. Columbia needlegrass and red avens cover < 1 percent 6

6a. Bluebunch wheatgrass cover ≥ 5 percent 7

7a. Sites located near Dickinson Park on lateral glacial moraines; soils derived from compacted granitic glacial till .... **Idaho fescue-bluebunch wheatgrass, Ledgefork Family ET [p. 287]**

7b. Sites not as above .... Undefined type or not Idaho fescue series

6b. Bluebunch wheatgrass cover < 5 percent .... Depauperate or undefined type or not Idaho fescue/grassland series

3b. Idaho fescue cover < 5 percent 8

8a. Bluebunch wheatgrass (*Elymus spicatus*) cover ≥ 5 percent .... Bluebunch wheatgrass series [9]

9a. Mock goldenweed (*Stenotus* spp.) cover ≥ 5 percent 10

10a. Limestone shoulders and summits; soil surface dominated by an erosion pavement of limestone flagstones .... **Bluebunch wheatgrass-Sandberg bluegrass-mock goldenweed -- Scabland, Paunsaugunt Family ET [p. 290]**

10b. Sites not as above .... Undefined type or not Bluebunch wheatgrass series

9b. Mock goldenweed cover < 5 percent 11

11a. Sandberg bluegrass (*Poa secunda*) co-dominant with bluebunch wheatgrass 12

12a. Soils derived from granitic glacial till and located on steep, lateral glacial moraines in Sinks Canyon .... **Bluebunch wheatgrass-Sandberg bluegrass, Wabek Family ET [p. 293]**

12b. Other soils or locations .... Undefined type or not Bluebunch wheatgrass series

11b. Sandberg bluegrass not sharing dominance with bluebunch wheatgrass .... Depauperate or undefined type or not Idaho fescue/grassland series

8b. Bluebunch wheatgrass cover < 5 percent .... Depauperate or undefined type or not grassland/upland series

III. Riparian and Wetland Ecological Types

1a. **Quaking aspen (*Populus tremuloides*) present and reproducing successfully with cover ≥ 5 percent** .... **Quaking aspen Series [2]**

2a. Sitka alder (*Alnus viridis* var. *sinuata*) and/or red-osier dogwood (*Cornus sericea*) present with cover ≥ 5 percent either singly or collectively 3

3a. Landform slope typically < 10 percent AND soils saturated within a meter of the soil surface throughout the growing season .... **Quaking aspen/red-osier dogwood - Sitka alder Habitat Type, Mantador Family ET [p. 244]**

3b. Landform slope typically ≥ 10 percent AND soil surface periodically flooded early in the growing season and/or soils saturated for only a short period during the growing season .... **Quaking aspen/red-osier dogwood - Sitka alder Habitat Type, Caryville Family ET [p. 244]**

3c. Sites or soils not as above .... Undefined type or not quaking aspen series

2b. Sitka alder and red osier dogwood combined cover < 5 percent 4

4a. Sticky purple geranium (*Geranium viscosissimum*) and/or starry false lily of the valley (*Maianthemum stellatum*) present .... **Quaking aspen/sticky purple geranium, Bullflat Family ET [p. 235]**

4b. Sticky purple geranium and starry false lily of the valley absent .... Undefined type or not quaking aspen series

1b. Quaking aspen cover < 5 percent and/or not reproducing successfully 5

5a. Willow (Salix spp.) cover ≥ 25 percent .... Willow Series [6]

6a. Soils derived in part from granitic alluvium 7

7a. Landform slope ≤ 6 percent 8

8a. Soils saturated within a meter of the soil surface throughout the growing season 9

9a. Sedge (*Carex aquatilis*, *C. utriculata*, *C. vesicaria*, *C. scopulorum*), and/or grass (*Deschampsia caespitosa*, *Calamagrostis canadensis*) cover ≥ 25 percent either singly or collectively 10

10a. Sites located along the periphery of kettle lakes on the Louis Lake moraine .... **Willow/Sedge - Kettle Lake, Fluvaquentic Cryaquepts ET [p. 304]**

10b. Other sites .... **Willow/Sedge, Moose River Family ET [p. 299]**

9b. Sedge and grass cover < 25 percent .... Undefined type

8b. Soils saturated within a meter of the soil surface for only a short period during the growing season 11

11a. Sedge (*C. scopulorum, C. nigricans*), and/or grass (*Deschampsia caespitosa*, *Calamagrostis canadensis*) cover ≥ 25 percent either singly or collectively .... **Oxyaquic soils, Elvick Family ET [p. 304]**

11b. Mesic forbs (*Senecio triangularis*, *Saxifraga odontoloma*, *Parnassia fimbriata*, *Mertensia ciliata*, *Geranium viscosissimum*, *Heracleum sphondylium* var. *lanatum*, *Erigeron peregrinus* var. *scaposus*, *Aquilegia coerulea*) cover ≥ 25 percent either singly or collectively

.... **Willow/Sedge, Moose River Family ET [p. 299]**

8c. Other soils .... Undefined type or not riparian series

7b. Landform slope > 6 percent .... Undefined type

6b. Other soils .... Undefined type

5b. Willow cover < 25 percent 12

12a. Sedge (*Carex aquatilis, C. utriculata, C. vesicaria, C. scopulorum, C. nigricans*), and/or grass (*Deschampsia caespitosa, Calamagrostis canadensis*) cover ≥ 25 percent either singly or collectively .... Graminoid Series [13]

13a. Soils derived in part from granitic alluvium 14

14a. Landform slope ≤ 6 percent 15

15a. Soils saturated within a meter of the soil surface throughout the growing season .... **Willow/Sedge, Moose River Family ET [p. 299]**

15b. Soils saturated within a meter of the soil surface for only a short period during the growing season .... **Oxyaquic soils, Elvick Family ET [p. 304]**

15c. Other soils .... Undefined type or not riparian series

14b. Landform slope > 6 percent .... Undefined type

13b. Other soils .... Undefined type

12b. Sedge and grass cover < 25 percent .... Depauperate or undefined type, or rerun the Ecological Type Key with cutoff levels reduced as follows: 25 percent = 10 percent; 10 percent = 5 percent; 5 percent = 1 percent (and reproducing for tree species) , 1 percent = present; or try the Environment Key.

Environment Key

Overview

The Environment Key is provided (1) to reduce the number of possible Ecological Types based on a given set of environmental attributes, (2) for office users who are interested in identifying the set of Ecological Types that might occur at sites located on topographic maps or GIS data, (3) to identify potential natural vegetation and Ecological Types at disturbed sites.

The Environment Key is a dichotomous key based on the environmental data collected during the field sampling effort. The Key is fashioned after the results of a tree classifier and also reflects the knowledge of, and observations made by, the field researcher. The Key is dichotomous, but given the environmental amplitude shown by many of the Ecological Types, terminal nodes often result in more than one possible ecological type. It is important to note that (1) the Environment Key is not exhaustive of the possible environmental conditions present along the eastern slope of the WRR, and (2) cut-off values are approximate.

Environment Key

1a. Igneous or metamorphic bedrock geology AND sites other than the South Pass Granite-Greenstone Belt 2

- 2a. Elevations < 3000 m 3
  - 3a. Soil parent materials glacial till or alluvium 4
    - 4a. Glacial till 5
      - 5a. Summits, shoulders, backslopes, and footslope 6
        - 6a. Elevations < 2750 m .... **Lodgepole pine/common juniper, Holland Lake Family ET [p. 206]**
          Lodgepole pine/russet buffaloberry, Bohica Family ET [p. 211]
          Mountain big sagebrush/Idaho fescue, Corbly 351L Family ET [p. 279]
          Bluebunch wheatgrass-Sandberg bluegrass, Wabek Family ET [p. 293]
        - 6b. Elevations ≥ 2750 m .... **Whitebark pine/grouse whortleberry, Salt Chuck Family ET [p. 145]**
      - 5b. Toeslopes along the periphery of kettle lakes on the Louis Lake moraine .... **Willow/Sedge - Kettle Lake, Fluvaquentic Cryaquepts ET [p. 304]**
    - 4b. Alluvium .... **Willow/Sedge, Moose River Family ET [p. 299]**
      Quaking aspen/sticky purple geranium, Bullflat Family ET [p. 235]
      Quaking aspen/red-osier dogwood - Sitka alder Habitat Type, Mantador Family ET [p. 244]
      Quaking aspen/red-osier dogwood - Sitka alder Habitat Type, Caryville Family ET [p. 244]
      Oxyaquic soils, Elvick Family ET [p. 304]
  - 3b. Soil parent materials colluvium or residuum 7
    - 7a. Shoulders and summits .... **Whitebark pine/Ross' sedge, Como Family ET [p. 153]**
      Limber pine/common juniper, Como Family ET [p. 197]
      Lodgepole pine/Ross' sedge, Targhee Family ET [p. 221]
      Lodgepole pine/Ross' sedge, Stecum Family ET [p. 231]
      Wyoming three-tip sagebrush/Idaho fescue, Ledgefork Family ET [p. 248]
    - 7b. Backslopes and footslopes 8
      - 8a. North- and east-facing slopes .... **Subalpine fir/grouse whortleberry, Elting Family ET [p. 105]**
        Warm subalpine fir forests, Elting Family ET [p. 115]

Lodgepole pine/Ross' sedge, Targhee Family ET [p. 221]

8b. South- and west-facing slopes .... **Whitebark pine/Ross' sedge, Como Family ET [p. 153]**
Whitebark pine/Ross' sedge, Frisco Family ET [p. 149]
Lodgepole pine/Ross' sedge, Targhee Family ET [p. 221]
Quaking aspen/Utah snowberry - Boulder, Ledgefork Family ET [p. 240]
Mountain big sagebrush/Idaho fescue, Ledgefork Family ET [p. 262]
Idaho fescue-bluebunch wheatgrass-Columbia needlegrass, Elwood Family ET [p. 284]

2b. Elevations ≥ 3000 m 9

9a. Sites at or below timberline (ca. 3200 m) 10

10a. Soils derived from glacial till or alluvium 11

11a. Soils derived from glacial till 12

12a. Lateral moraines 13

13a. North- and east-facing slopes
.... **Subalpine fir/grouse whortleberry, McCall Family ET [p. 100]**
Subalpine fir/grouse whortleberry, Swapps Family ET [p. 131]
Subalpine fir/gooseberry currant, Cranbay Family ET [p. 131]
Krummholz, Klootch Family ET [p. 136]

13b. South- and west-facing slopes
.... **Whitebark pine/grouse whortleberry, Jeru Family ET [p. 140]**
Krummholz, Klootch Family ET [p. 136]
Idaho fescue-bluebunch wheatgrass, Ledgefork Family ET [p. 287]

12b. Ground moraines .... **Whitebark pine/grouse whortleberry, Jeru Family ET [p. 140]**
Parry's rush, Oxyaquic Cryorthents ET [p. 294]

11b. Soils derived from alluvium .... **Willow/Sedge, Moose River Family ET [p. 299]**
Oxyaquic soils, Elvick Family ET [p. 304]

10b. Soils derived from colluvium and/or residuum .... **Whitebark pine/grouse whortleberry, Jeru Family ET [p. 140]**
Whitebark pine/grouse whortleberry, Elting Family ET [p. 158]
Whitebark pine/grouse whortleberry, Sig Family ET [p. 158]
Subalpine fir/gooseberry currant, Elting Family ET [p. 95]

Krummholz, Klootch Family ET [p. 136]

9b. Sites above timberline 14

14a. Sites located in late snowbank environments .... **Late snowbank vegetation, Hargran Family ET [p. 85]**
Snow willow/Bellardi bog sedge, McCall Family ET [p. 81]

14b. Other sites 15

15a. Riparian zones and wetlands .... **Oxyaquic soils, Elvick Family ET [p. 304]**

15b. Glacial cirques, avalanche paths, and sheltered slope positions .... **Snow willow/Bellardi bog sedge, McCall Family ET [p. 81]**

15c. Exposed, windy alpine slopes, shoulders, and summits .... **Ross' avens-Blackroot sedge Alpine Turf, Agneston Family ET [p. 76]**
Ross' avens Alpine Fellfield, McCall Family ET [p. 72]

1b. Sedimentary bedrock geology or sites located in the South Pass Granite-Greenstone Belt 16

16a. Sites located in the South Pass Granite-Greenstone Belt 17

17a. Shoulders, summits, and exposed backslopes 18

18a. White River Formation .... **Low sagebrush/Idaho fescue Habitat Type [please refer to Tweit and Houston (1980)]**

18b. Other geologic formations of the South Pass Granite-Greenstone Belt .... **Mountain big sagebrush/Idaho fescue, Corbly 166D Family ET [p. 266]**
Mountain big sagebrush/Idaho fescue, Lithic Argiustolls ET [p. 270]

17b. Sheltered backslopes, footslopes, and toeslopes **19**

19a. Sheltered backslopes and footslopes .... **Lodgepole pine Series, Corbly Family ET [p. 226]**

19b. Toeslopes .... **Willow/Sedge, Moose River Family ET [p. 299]**

16b. Sites located in sedimentary bedrock geology 20

20a. Upland sites 21

21a. North- and east-facing slopes 22

22a. Soils derived exclusively from sandstone or sandy-shale 23

23a. Summits, shoulders, and upper backslopes
.... **Lodgepole pine/heartleaf arnica, Como Family ET [p. 216]**
Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]
Whitebark pine Series, Marosa Family ET [p. 159]

23b. Lower backslopes and footslopes
.... **Lodgepole pine/Oregon grape, Agneston Family ET [p. 201]**
Lodgepole pine/grouse whortleberry, Telcher Family ET [p. 231]
Subalpine fir/grouse whortleberry, Marosa Family ET [p. 110]

22b. Soil derived at least in part from limestone and/or dolomite 24

24a. Soils derived from limestone and/or dolomite colluvium over granitic glacial till. Primarily located in Sinks Canyon, but may occur in other deep canyons where piedmont glacial deposits occur, including Bull Lake Creek canyon, and the Whiskey Basin - Torrey Creek canyon areas
.... **Douglas-fir/Rocky Mountain maple, Yourame Family ET [p. 178]**

24a. Other soils 25

25a. Upper slope positions
.... **Douglas-fir/common juniper, Shawmut family ET [p. 172]**
Douglas-fir/Utah snowberry, Typic Calciustepts ET [p. 178]
Douglas-fir/Oregon grape, Cloud Peak Family ET [p. 167]
Subalpine fir/Oregon grape, Frisco Family ET [p. 120]
Limber pine/common juniper, Lolo Family ET [p. 181]

25b. Lower slope positions
.... **Douglas-fir/Rocky Mountain maple, Redfist Family ET [p. 161]**
Subalpine fir/heartleaf arnica - Cold Air Drainage, Hierro Family ET [p. 125]
Quaking aspen/sticky purple geranium, Bullflat Family ET [p. 235]

21b. South- and west-facing slopes 26

26a. Soils derived from limestone and/or dolomite colluvium over granitic glacial till primarily in Sinks Canyon
.... **Mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET [p. 274]**

26b. Soils derived from limestone, dolomite, shale, and/or siltstone 27

27a. Upper slope positions 28

28a. Soils derived from residuum

.... **Limber pine/common juniper, Tyzak Family ET [p. 187]**

Bluebunch wheatgrass-Sandberg bluegrass-mock goldenweed -- Scabland, Paunsaugunt Family ET [p. 290]

28b. Soils derived from colluvium over residuum

.... **Douglas-fir/common juniper, Shawmut family ET [p. 172]**

Limber pine/common juniper, Lolo Family ET [p. 181]

Limber pine/spike fescue, Saddlehorse Family ET [p. 192]

Mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET [p. 274]

Wyoming three-tip sagebrush/bluebunch wheatgrass, Bigsheep Family ET [p. 252]

27b. Lower slope positions

.... **Mountain big sagebrush/Idaho fescue, Shawmut Family ET [p. 258]**

Mountain big sagebrush/Idaho fescue, Kiev Family ET [p. 279]

20b. Riparian zones .... **Quaking aspen/sticky purple geranium, Bullflat Family ET [p. 235]**

Quaking aspen/red-osier dogwood - Sitka alder Habitat Type, Caryville Family ET [p. 244]

Ecological Type Descriptions

Contents of Ecological Type Descriptions

A descriptive section for each major Ecological Type contains the following:

Principal Species Descriptions—Presented at the beginning of each vegetation series. A narrative description of the general ecology and management considerations for the principal species (see "Nomenclature/title") of the habitat types included in the vegetation series. Prinicipal species descriptions for subordinate species (see "Nomenclature/title") are provided in Appendix 6.

Nomenclature/title—The name given to the Ecological Type (ET) beginning with the representative PNV, which may include functional group, series, or habitat type. Habitat type names include principal species first followed by subordinate species of different floristic layers (seperated by a forward-slash) and/or coprincipal species of the same floristic layer (seperated by a dash), The potential natural vegetation name is followed by the soil series family name. Geologic, geomorphic, and/or landform names were sometimes included in the name (following the PNV name and separated with a hyphen), thus indicating the importance of that landscape feature or process in the designation of the ET.

Title code—A shorthand version of the title consisting of the USDA Plants Database code (USDA NRCS 2007b) for the PNV.

Sample size (n =)—The number of sample plots used to describe the ET.

Landscape/ground cover/soil photograph—Photographs depicting a typical landscape, ground cover, and soil profile view for ETs with a sample size 3 or greater. Photos are by Aaron Wells unless otherwise indicated.

Distribution—A description of the areal extent of the ET, including Ecological Unit Classification, distribution across the study area, and soil map units in which the ET is a component.

Environment—A description of the environmental attributes typical of the ET, including slope aspect (with the number of sample plots of a given aspect class in brackets), landforms, landscape position, soil parentmaterials, bedrock geology, and climate.

Environment table—A summary table of quantitative environmental data (see Appendix 7 for a summary of environmental data for minor ETs [n<3]).

Potential natural vegetation (PNV)—Includes a descriptive section regarding the floristic attributes of the ET and the principal species table.

Descriptive section—A description of the floristic attributes of the ET.

Principal species table—A table including the common and Latin names, constancy, percentage cover, and range of cover for the characteristic species (typically ≥40% constancy) of the ET (see Appendix 8 for complete constancy/cover tables).

Constancy (CON)—A percentage of plots where a species occurs in the ET.

Cover (COV)—The average percentage foliar cover of a species on the plots where it is present (when it occurs) in the ET.

Range of cover (MIN/MAX)—The minimum and maximum percent foliar cover of a species when it occurs in the ET.

Soils—A general description of the soils typical of the ET, also includes soil photograph and typical pedon description.

Soil photograph—A photograph of a typical soil for the ET. This photo is most often of the typical pedon, but may include other soil profiles if the typical pedon photo was of low quality. Photos are by Aaron Wells unless otherwise indicated.

Typical pedon description—A narrative description of the typical pedon for major ET (n≥3). Generated from the NASIS report generator. Includes the soil classification and horizonation.

Soil classification—The full classification of the typical pedon from the ninth edition of the "Keys to Soil Taxonomy" (Soil Survey Staff 2003) (in the following order): particle-size class, mineralogy class, cation-exchange activity class, and soil subgroup.

Horizonation—A narrative description of each soil horizon, including horizon name, depths (cm) of upper and lower boundary, color, texture, structure, plasticity, roots, coarse fragments, and other miscellaneous descriptors.

Ecology—A narrative description of the ecological relationships important to the ET, including vegetation, soils, parent material, geomorphology, bedrock geology, and climate.

Succession (forested ETs only)—A narrative section describing likely successional pathways for the ET following a disturbance such as a forest fire or wind throw. Much of the information for this section was derived from Bradley and others (1992) "Fire Ecology of the Forest Habitat Types of Eastern Idaho and Western Wyoming."

Management considerations—A narrative section describing issues important in managing the ET. This section includes information on stand characteristics (forested ETs only), timber harvest, insects and disease, invasive plant species, prescribed and natural fire, wildlife, recreation, and livestock grazing.

Stand characteristics—Summary tables for the forested ETs, includes basal area, DBH, trees per ha, and site tree summaries by tree species.

Similar ecological types—A section listing the ecological type(s) similar to the ET being described, including similar type, floristic differences, and environmental differences.

Similar type—The full ecological type name of the similar type.

Floristic differences—A short narrative describing the key floristic attributes that differentiate the two Ecological Types.

Environmental differences—A short narrative describing the key environmental attributes that differentiate the two ecological type

Alpine Series

Principal Species Descriptions

Ross' avens

Geum rossii var. *turbinatum* (R. Br.) Ser. (Rydb.) C.L. Hitchc.

Ross' avens is a common, native forb that occurs in high alpine environments, typically above timberline, at elevations between 2,744 and 4,268 m, in northeastern Oregon, central Idaho, western and central Montana, Wyoming, northeastern Nevada, Utah, western Colorado, north-central New Mexico, and northern Arizona. On the east slope of the WRR in Wyoming, Ross' avens occurs between roughly 2,700 and 3,800 m (Massatti 2007).

Ross' avens is a perennial, rhizomatous herb with erect flowering stems arising from a woody caudex, and standing 5 to 15 cm tall (Scott 1995). The crowded basal leaves are pinnate to pinnatifid with oblanceolate to obovate, entire to coarsely three- to five-toothed leaflets. Stem leaves appear alternate and are sessile, pinnatifid, and reduced upwards. Flowers are yellow with five petals and numerous stamens. Reproduction occurs asexually via rhizomes, and sexually from pubescent, wind dispersed seeds.

Ross' avens occurs on all major rock types, including sedimentary, metamorphic, and igneous (Bamberg and Major 1968; Hess and Wasser 1982). However, evidence from Wyoming and Montana suggests that Ross' avens is less common on sedimentary rocks (Jones and Ogle 2000). Ross' avens grows on well-drained slopes and ridges, occurring across a wide range of slope exposures, snow depths, and plant communities. Ross' avens ranges from sheltered, mesic turf communities dominated by *Carex elynoides* or *Kobresia bellardi* to windswept, snow-free, xeric cushion plant communities characterized by erosion pavement, and cushion plants and low sedges, including *Silene acaulis*, *Trifolium nanum*, *T. parryi*, *Minuartia obtusiloba*, *Phlox* spp., and *Carex rupestris*, to landforms experiencing frost boils and active frost-sorting (Johnson and Billings 1962; Baker 1983; Jones and Ogle 2000). Ross' avens forms dense, continuous stands at sites less severe than those occupied by cushion plant communities but more severe than those occupied by sedge turf. The environmental flexibility and ubiquitous nature of Ross' avens, compared to other alpine species such as blackroot sedge, may be explained in part by its ability to store massive amounts of carbohydrates in roots and rhizomes (Mooney and Billings 1960). The large carbohydrate stores allow Ross' avens to survive in harsh unproductive sites, initiate growth beneath the late winter snowpack, and continue with rapid growth following snow melt.

The fire ecology of Ross' avens is unknown. In the rare event of a fire in the alpine zone, it is assumed, given the rhizomatous nature and carbohydrate storage ability, that this species would show a positive post-fire response. In a transplanting experiment in Colorado, strips of alpine turf were removed from natural communities and transplanted onto rehabilitation sites (Conlin and Ebersole 2001). Ross' avens in transplants showed a decrease in abundance within a year following transplanting compared to non-transplants. However, in another transplanting study conducted by May and others (1982) in Colorado, Ross' avens was successfully transplanted when complete root systems were carefully excavated and transplanted. Ross' avens may be a good choice for revegetation projects in the alpine zone when properly transplanted. Ross' avens has been identified in the food caches of pikas in the Rocky Mountains of Colorado (Johnson 1967). At severe, windswept sites in cushion plant communities, Ross' avens and associated species are sensitive to trampling. At more sheltered sites, in dense Ross' avens, blackroot sedge, and Bellardi bog sedge turf communities, Ross' avens and associated species are moderately resilient to trampling by hikers and livestock. Heavy trampling that damages the sod layer will result in the elimination of Ross' avens and associated species and the initiation of wind erosion in high use areas.

Blackroot Sedge and Bellardi Bog Sedge

Carex elynoides Holm and *Kobresia myosuroides* (Vill.) Fiori

Blackroot and Bellardi bog sedge are native, densely tufted alpine sedges that share many ecological and morphological characteristics, and are therefore treated together in the following section.

Bellardi bog sedge is a circumboreal species that occurs at high latitudes across Alaska, northern Canada, Greenland, Europe, and Asia (Ball 2002). At lower latitudes, Bellardi bog sedge occurs in all Canadian Provinces except Saskatchewan, Nova Scotia, New Brunswick, and Prince Edward Island, and across the western United States except Washington, Montana, Nevada, and Arizona. Blackroot sedge has a much more limited geographic extent, occurring only in Montana, Idaho, Nevada, Utah, Wyoming, Colorado, and New Mexico (Ball and Reznicek 2002). The elevation range of Bellardi bog sedge is strongly dictated by latitude but generally occurs just below or above tree line. However, in the high arctic, Bellardi bog sedge occurs at or near sea level. At their southern geographic limits, both blackroot and Bellardi bog sedge are limited to high alpine environments greater than 3,200 m. Across much of the Pacific Northwest and the central and northern Rocky Mountains, both species typically occur above timberline, between 2,439 and 4,268 m. On the east slope of the WRR in Wyoming, these two species occur between roughly 2,800 and 3,800 m (Massatti 2007).

Blackroot and Bellardi bog sedge are caespitose, nonrhizomatous, sod-forming sedges with wiry flowering stems standing 5 to 20 cm tall (Ball 2002; Ball and Reznicek

2002). The solitary flowering spikes are androgynous in both species. The perigynia of Bellardi bog sedge are 2 to 3.5 mm long and are split nearly the entire length, while the perigynia of blackroot sedge are 2 to 4 mm long and entire throughout. The split pergynia is the most obvious means of distinguishing between the two species. Both reproduce sexually via tiny seeds called achenes, and vegetatively by root sprouting.

Blackroot sedge and Bellardi bog sedge have both been characterized as calcicoles, or plant species requiring calcareous substrates (Bamberg and Major 1968; Jones and Ogle 2000). However, both species are known to also occur on siliceous substrates throughout the Rocky Mountains (Johnson and Billings 1962; Cooper and others 1997; Komarkova and Webber 1978). Bamberg and Major (1968) suggested that these species may be obligate calcicoles across the arctic and northern Rocky Mountains but have adapted to the extensive siliceous substrates in the southern and central Rocky Mountains. Blackroot sedge and Bellardi bog sedge have both been described as inhabiting broad, well-drained, windswept upper slopes above timberline (Douglas and Bliss 1977; Walker and others 1993). However, observations from Colorado and New Mexico suggest that blackroot sedge tends to occur in drier, harsher, more exposed sites with little to no winter snow accumulation, while Bellardi bog sedge tends to occur in more mesic, sheltered sites with low to moderate snow accumulations (26–50 cm), including north-facing slopes, slight depressions on windward slopes, and glacial cirques (Baker 1983; Walker and others 1993; Boyce and others 2005).

The fire ecology of blackroot sedge and Bellardi bog sedge is unknown. In the rare event of a fire in the alpine zone, it is assumed, given the dense sod created by these species and their ability to reproduce vegetatively, that post-fire response would be positive. In a transplanting experiment in Colorado, strips of alpine turf were removed from natural communities and transplanted onto rehabilitation sites (Conlin and Ebersole 2001). Blackroot sedge in transplants showed no difference in abundance in the years following transplanting than non-transplants. Blackroot sedge may be a good choice for revegetation projects in the alpine zone using transplants. Blackroot sedge is considered an important forage species for domestic livestock, especially sheep (Hermann 1970). Bellardi bog sedge has been identified in the food caches of pikas in the Rocky Mountains of Colorado (Johnson 1967). It is likely that blackroot sedge also composes a portion of the diet of pikas, especially in areas where the two species coexist. The dense sod created by blackroot and Bellardi bog sedge is extremely important in mitigating the effects of wind on soil erosion at the exposed, high elevation sites characteristic of these two species. Blackroot and Bellardi bog sedge are moderately resilient to trampling by hikers and livestock. Heavy trampling that damages the sod layer will result in the elimination of these sedges and the initiation of wind erosion in high use areas.

Arctic Willow and Snow Willow

Salix arctica var. *petraea* (Anderss.) Bebb and *Salix reticulata* var. *nana* L. (Hook.) Anderss.

Arctic and snow willows are native, deciduous, prostrate, alpine shrubs that share many ecological and morphological characteristics, and are therefore treated together in the following section.

Arctic and snow willows are circumboreal species that occur throughout the high latitudes in North America, Europe, and Asia (Scott 1995). In western North America, south of the boreal and arctic regions, arctic and snow willows occur in all major alpine regions of the Rocky Mountains from British Columbia and Alberta into Montana, Idaho, Wyoming, and Colorado (USDA NRCS 2007b). In Washington, arctic willow is limited to the extreme northern Cascade Range, while snow willow occurs throughout the Cascade, central Coast, and Olympic Ranges. In Oregon, arctic and snow willows are limited to the Wallowa, Elkhorn, and Strawberry Mountain Ranges in the northeastern part of the state. Small populations of arctic and snow willow also occur in mountain ranges of northern Nevada. The Sierra Nevada Mountains of California; the Wasatch, Uinta, and LaSal Mountains of Utah; and the San Juan Mountains of New Mexico represent the southern limits of these two alpine willow species.

Arctic and snow willows are both creeping, mat-forming, perennial shrubs that are typically less than 5 to 8 cm in height (Fertig and Markow 2001). Arctic willow features elliptic to ovate leaves that are pointed at the tip and dull green in color, while the leaves of snow willow are elliptic to ovate, rounded at the tip, dark green, and leathery in texture. The pistillate catkins are 1 to 5 cm long and occur on leafy flowering branchlets, while those of snow willow are generally shorter (0.5–2 cm) and occur on naked, flowering branchlets. Both species are shallow rooting (5–40 cm), and vegetative reproduction is accomplished by rooting of stem nodes (Dawson 1990).

The elevation range of arctic and snow willow is strongly dictated by latitude but generally occurs just below or above tree line (Ladyman 2004b). In the high arctic, these willows occur at or near sea level but are limited to high alpine environments greater than 3,350 m at their southern geographic limits. Across much of the Pacific Northwest and the central and northern Rocky Mountains, both species typically occur between 2,469 and 4,085 m. On the east slope of the WRR in Wyoming, arctic and snow willows occur between roughly 2,700 and 4,100 m (Massatti 2007). Arctic and snow willows occur on all major rock types, including igneous, sedimentary, and metamorphic. Soils where arctic and snow willows occur tend to have loamy, organic rich surface horizons (Brunsfeld and Johnson 1985). Snow willow is also found growing on moist, sandy, and gravelly soils.

Arctic and snow willows often co-occur within the same general vicinity. However, each species features specific soil moisture requirements that result in microhabitat partitioning (Dawson 1990). Arctic willow is more general in its habitat type preferences than snow willow but most often inhabits moist, sheltered microsites, including late snowbank sites, solufluction terraces, seeps, and moist meadows. Unlike snow willow, arctic willow is dioecious and features intersexual differences in ecology and physiology (Dawson and Bliss 1989a, 1989b; Jones and others 1999). Snow willow is found predominantly at exposed, xeric sites, including windward slopes, fellfields, and dry turf (Dawson 1990). Snow willow features an extensive, fine-textured, rhizomatous root system that is highly efficient in collecting water and nutrients. Snow willow conserves water through fine-tuning its tissue osmotic properties, allowing it to survive in water-limited conditions.

The fire ecology of arctic and snow willows is unknown. In the rare event of a fire in the alpine zone, it is assumed, given their low stature and ability to reproduce vegetatively, that post-fire response would be positive. Arctic and snow willows are sensitive to trampling by hikers and livestock, which can lead to stem damage and disruption of the shallow roots. Johnson (1967) identified willows (*Salix* spp.) in the food caches of pikas in the Rocky Mountains of Colorado. It is likely arctic and snow willows compose a portion of the diet of pikas and perhaps also marmots. Arctic and snow willow are important in stabilizing soils from frost heaving and erosion by wind and water.

Grayleaf Willow

Salix glauca var. *villosa* L. Anderss.

Grayleaf willow occurs throughout the northern and western portion of Canada from Newfoundland northwest to northern Yukon Territory and south through British Columbia and Alberta (Uchytil 1992). Grayleaf willow occurs throughout most of Alaska, with the exception of the Aleutian chain and the southeastern coastline. In the lower 48 states, grayleaf willow occurs in subalpine and alpine environments of Montana, Wyoming, eastern Idaho, Colorado, Utah, and northern New Mexico.

On the Shoshone National Forest in Wyoming, grayleaf willow occurs most often in the upper-forested zone and alpine zone between 3,000 and 3,300 m elevation but may occur as low as 2,600 m and as high as 3,800 m (Fertig and Markow 2001). At or below timberline, this species typically appears as a low shrub (<1 m), growing along subalpine streams, lakes, snow melt-water and avalanche paths, and in krummholz vegetation. Above timberline, it is much reduced in stature (<10 cm), making it difficult to differentiate from other prostrate willows, such as arctic willow. Above timberline, this species may be found growing in late snowbank environments and on sheltered slopes in alpine turf.

Grayleaf willow is a dioecious shrub with densely hairy twigs and 3- to 8-cm long elliptic to oblanceolate leaves that are bright green above and glaucous below (Fertig and Markow 2001). The pistillate catkins are typically 2 to 5 cm long with pubescent capsules, while staminate catkins are 1.2 to 3 cm long with hairy, light brown to black flowering bracts. Regeneration is primarily sexual via small, lightweight seeds that overwinter under the snow and germinate soon after the spring thaw in exposed mineral soil (Uchytil 1992). Grayleaf willow also reproduces asexually by sprouting from the rootcrown or a stembase that has been damaged.

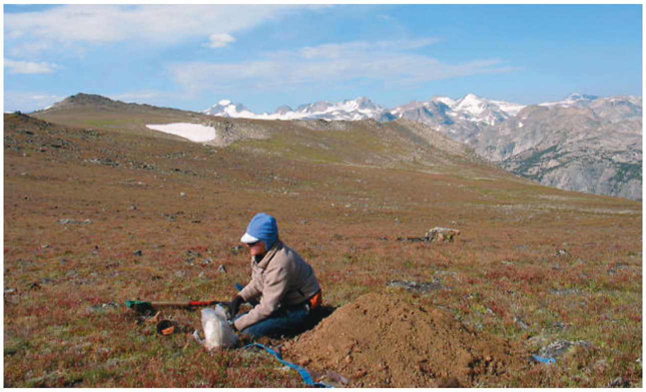
Grayleaf willow is intolerant of shade and prefers rocky, well-drained soils (Uchytil 1992). Grayleaf willow is tolerant of low to moderate fire and will resprout quickly from the rootcrown following a burn. However, severe fires that burn through the upper soil horizon will destroy the roots, thus killing the plant. Following severe fires, grayleaf willow regenerates from seeds, which sprout quickly in the broad areas of mineral soil exposed by the fire. Grayleaf willow is tolerant of heavy browsing and is an important source of nutrition for moose.

Ross' Avens Alpine Fellfield, McCall Family Ecological Type

Geum rossii var. *turbinatum* Alpine Fellfield, McCall Family ET

GEROT Alpine Fellfield, McCall Family ET

N = 5



Distribution

The Ross' avens Alpine Fellfield, Agneston Family Ecological Type occurs within the alpine zone ecoregion of Chapman and others (2004). This ecological type occurs from Union Peak in the northwest to Atlantic Peak in the southeast. It is a component of map unit 304L.This ecological type occurs in the Alpine Zone Ecoregion on windward positions on ridges, steep slopes, and summits, and on dry, high-level erosion surface remnants of moderate slope gradient (<30%), including Ram Flat, Goat Flat, and Horse Ridge in the northern study area, and Roaring Fork Mountain and Cathedral Peak in the southern study area.

Environment

Aspect: Northwest [1], south [1], southwest [1], west [1], west-northwest [1].

Landforms and Landscape Position: Windward slopes on alpine ridges, mountain summits, upper extent of glacial cirques. Summits, shoulders, backslopes.

Parent Materials: Colluvium over residuum, residuum, granitic glacial till.

When this type occurs in glacial cirques, parent material is granitic glacial till.

When this type occurs on alpine slopes, summit erosion surfaces, and mountain summits, parent materials are (1) colluvium over residuum when slope gradient > approximately 25%, or (2) residuum when slope gradient < approximately 25%.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss, and migmatite.

In the southern study area near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, bedrock tends to be granodiorite of the Louis Lake Pluton. In the southern study area north of the North Fork Popo Agie River, bedrock tends to be porphyritic quartz monzonite. In the northern study area, including Ram Flat, Goat Flat, and Horse Ridge, bedrock tends to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 85 to 93 cm.

Additional environment data summaries are provided in Table 7.

Potential natural vegetation

The potential natural vegetation of this ecological type is similar to the Ross' avens dry alpine turf described by Johnson and Billings (1962). Ross' avens is the dominant species. Blackroot sedge occurs at low abundance (≤5%) and may be completely absent at the most exposed, windy sites. Cushion plants, including cushion phlox, moss campion, dwarf clover, lance-leaved stonecrop, and twinflower sandwort, are quite common at these windswept sites. Other common herbaceous species are alpine sagebrush, Rocky Mountain fescue, American bistort, varileaf cinquefoil, Sandberg bluegrass, arctic bluegrass, northern singlespike sedge, spike trisetum, curly sedge, and common woodrush. Table 8 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the GEROT Alpine Fellfield, McCall Family ET were deep with a low degree of soil development, high coarse fragments (avg. 68%), and low clay (avg. 12%).

One soil located on an unglaciated alpine ridge featured a 20 cm thick Bt-horizon between the A- and Bw-horizons. A typical soil featured an A/Bw/C horizonation. Diagnostic soil horizons include a mollic (avg. 38-cm thick) or umbric epipedon (avg. 35-cm thick) and a cambic horizon (avg. 42-cm thick). Particle size class was loamy-skeletal. Soils were Typic Dystrocryepts [1] and Humic Dystrocryepts [4].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Humic Dystrocryepts

A—0 to 33 cm: very dark brown (10YR 2/2) extremely stony very fine sandy loam, very dark grayish brown (10YR 3/2), dry; 53%sand; 10% clay; weak fine granular structure; very friable, soft, slightly sticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 4% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 61% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0; clear wavy boundary.

Bw1—33 to 51 cm: dark yellowish brown (10YR 4/4) extremely bouldery coarse sandy loam, light yellowish brown (10YR 6/4), dry; 73% sand; 14% clay; weak very fine subangular blocky structure; friable, soft, slightly sticky, nonplastic; many very fine and fine roots and common medium roots and few coarse roots; many very fine and fine and common medium and few coarse pores; 17% patchy faint clay films on rock fragments; 6% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 17% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 30% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 39% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear smooth boundary.

Bw2—51 to 82 cm: brown (10YR 4/3) extremely stony fine sandy loam, pale brown (10YR 6/3), dry; 67% sand; 15% clay; weak medium platy structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 2% patchy faint silt coats on all faces of peds and 3% patchy faint silt coats between sand grains and 24% patchy distinct clay films on top surfaces of rock fragments; 10% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 19% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 44% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; clear smooth boundary.

C—82 to 93 cm: olive brown (2.5Y 4/3) extremely stony loamy sand, light yellowish brown (2.5Y 6/3), dry; 86% sand; 6% clay; single grain; loose, nonsticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 5% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 13% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 66% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; hit a restricting stone at 93 cm (roots observed at bottom of pit, therefore assuming a deep pit).

Ecology

Fellfields are alpine sites characterized by relatively flat relief, very stony soils, and low, often widely spaced plants (Daubenmire 1978). Fellfields occupy some of the most exposed, windy sites in the alpine environment and experience no snow accumulation during the winter months. The lack of snow exposes the plants inhabiting these sites to extremely cold winter temperatures, intense desiccation from winter winds, and physical abrasion by snow and ice particles. "Cushion" plants and Ross' avens occupy these sites dominated by rock, gravels, and erosion pavement (Johnson 2004). Blackroot sedge is densely caespitose sedge that is resilient to the cold, dry, windy conditions typical above timberline. Blackroot sedge occurs along a continuum from extremely windswept sites characterized by cushion plant communities to sheltered sites near timberline. The GEROT Alpine Fellfield, McCall Family ET represents sites near or above the upper limit of blackroot sedge. Ross' avens is more general in its habitat preference than blackroot sedge, in part due to its ability to store large amounts of carbohydrates in roots and rhizomes, which may explain its ability to survive at these harsh sites (Mooney and Billings 1960). On high-level erosion surface remnants and mountain slopes, this ET is commonly associated with slopes experiencing various types of frost action, especially stone stripes, which are best expressed on slopes between 7 and 27% gradient (Richmond 1949).

Management considerations

This ecological type occurs almost entirely within wilderness boundaries. Trampling by hikers and pack- and grazing-animals is the most important management issue concerning the GEROT Alpine Fellfield, McCall Family ET. This ecological type is tolerant of low levels of trampling. Moderate to heavy trampling can damage the cushion plants and result in the initiation of wind erosion. Managers should encourage backpackers and wranglers to stay on maintained trails. When traveling off-trail, recreationists can mitigate the effects of trampling by (1) spreading out across the landscape, and (2) traveling on hard surfaces such as boulder, stone, or talus slopes whenever common sense and safety dictates.

Similar ecological types

Ecological Type 1

Type: Ross' avens—Blackroot sedge Alpine Turf, Agneston Family ET

Floristic differences: The two types differ floristically in that the McCall Family ET has little to no blackroot sedge and is characterized by discontinuous vegetation, erosion pavement, and abundant cushion plants, while the Agneston Family ET is characterized by abundant blackroot sedge and a more continuous vegetation cover.

Environmental differences: The two types differ environmentally in that the McCall Family ET is located on the most exposed, windswept sites that experience little to no snow accumulation, while the Agneston Family ET is located on slightly more sheltered sites that experience low to moderate snow accumulation. The second difference is that the soils of the McCall Family (Inceptisols) are relatively low in clay when to compared soils in the Agneston Family ET (Alfisols).

Ecological Type 2

Type: Snow willow/Bellardi bog sedge, McCall Family ET

Floristic differences: The two types differ floristically in that the Ross' avens Fellfield, McCall Family ET has little to no snow willow or Bellardi bog sedge and is characterized by discontinuous vegetation, erosion pavement, and abundant cushion plants, while the snow willow/Bellardi bog sedge, McCall Family ET is characterized by a dense sod with abundant snow willow and Bellardi bog sedge.

Environmental differences: The two types differ environmentally in that the Ross' avens Fellfield, McCall Family ET is located on the most exposed, windswept sites that experience little to no snow accumulation, while the Snow willow/Bellardi bog sedge, McCall Family ET is located on more sheltered sites that experience moderate to high snow accumulation and relatively abundant soil moisture throughout the year.

Table 7—Summary of environmental variables for the GEROT Alpine Fellfield, McCall Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,454	3,329	3,530
Slope (%)	24	12	34
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	889	850	931
degree days	7,534	6,959	8,973
frost-free days	14.6	14.2	15.7
site water balance (mm/year)	-90	-131	-62
average annual temperature (°C)	-2.2	-2.5	-1.6
Total annual potential evapotranspiration (mm)	322	288	408
summer radiation (KJ)	20,160	19,280	20,860
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	68	43	84
Clay (% in particle size control section)	12	7	17
pH (in particle size control section)	4.8	4.8	5
Available water capacity (mm/m)	39	22	52
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil, < 2 mm fraction (%)	2	0	5
Exposed bedrock	9	0	45
Gravel	3	1	5
Cobble	9	5	15
Stones	15	10	20
Boulders	6	2	10
Litter	13	5	20
Wood	0	0	0
Moss and lichen	7	2	15
Basal vegetation	45	25	55
Water	0	0	0

Table 8—Constancy/cover table for common plant species occurring in the GEROT Alpine Fellfield, McCall Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Forbs:						
ANUM	*Antennaria umbrinella*	Umber pussy-toes	40	3	3	3
ARSC	*Artemisia scopulorum*	Alpine sagebrush	80	4	3	5
ASTRA	*Astragalus*	Milk-vetch	40	1	1	1
ERLA	*Erigeron lanatus*	Woolly fleabane	40	1	1	1
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens	100	15	10	20
HYGR5	*Hymenoxys grandiflora*	Graylocks four-nerve daisy	60	1	1	1
MIOB2	*Minuartia obtusiloba*	Twinflower sandwort	60	3	1	5
ORAL4	*Oreostemma alpigenum*	Tundra aster	40	2	1	3
OXCA4	*Oxytropis campestris*	Slender crazyweed	40	4	3	5
PHPU5	*Phlox pulvinata*	Cushion phlox	80	2	1	3
POBI6	*Polygonum bistortoides*	American bistort	100	2	1	5
PODI2	*Potentilla diversifolia*	Varileaf cinquefoil	100	3	1	5
POVI	*Polemonium viscosum*	Sticky polemonium	40	1	1	1
SARH2	*Saxifraga rhomboidea*	Diamondleaf saxifrage	40	1	1	1
SELA	*Sedum lanceolatum*	Lance-leaved stonecrop	80	2	1	3
SIACS2	*Silene acaulis* var. *subacaulescens*	Moss campion	100	1	1	3
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	60	2	1	3
TRNA2	*Trifolium nanum*	Dwarf clover	60	5	1	10
Grasses:						
CAPU	*Calamagrostis purpurascens*	Purple reedgrass	40	6	1	10
ELTR7	*Elymus trachycaulus*	Slender wheatgrass	40	2	1	3
FEBR	*Festuca brachyphylla*	Alpine fescue	60	2	1	3
FESA	*Festuca saximontana*	Rocky Mountain fescue	80	4	1	10
POAR2	*Poa arctica*	Arctic bluegrass	60	2	1	3
POSE	*Poa secunda*	Sandberg bluegrass	80	7	3	15
TRSP2	*Trisetum spicatum*	Spike trisetum	80	2	1	3
Graminoids:						
CAEL3	*Carex elynoides*	Blackroot sedge	80	3	1	5
CAMA9	*Carex macloviana*	Falkland island sedge	40	2	1	3
CAPH2	*Carex phaeocephala*	Dunhead sedge	40	4	3	5
CARU3	*Carex rupestris*	Curly sedge	40	3	1	5
CASC10	*Carex scirpoidea*	Canadian single-spike sedge	60	8	3	10
LUMU2	*Luzula multiflora*	Common woodrush	80	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Ross' Avens—Blackroot Sedge Alpine Turf, Agneston Family Ecological Type

Geum rossii var. *turbinatum*—*Carex elynoides* Alpine Turf, Agneston Family Ecological Type

GEROT—CAEL3 Alpine Turf, Agneston Family ET

N = 4

Distribution

The Ross' avens-blackroot sedge Alpine Turf, Agneston Family Ecological Type occurs within the alpine zone ecoregion of Chapman and others (2004). This ecological type occurs from Union Peak in the northwest to Atlantic Peak in the southeast. It is a component of map unit 304L.

This ecological type occurs in the Alpine Zone Ecoregion on windward positions on moderately steep (< approximately 30%) ridges, mountain slopes and summits, and glacial cirque walls and on dry, high-level erosion surface remnants, including Ram Flat, Goat Flat, and Horse Ridge in the northern study area, and Roaring Fork Mountain and Cathedral Peak in the southern study area.

Environment

Aspect: Northeast [1], southwest [1], west-northwest [2]

Landforms and Landscape Position: Windward slopes on alpine ridges and mountain peaks, high-level erosion surface remnants. Shoulders, backslopes, footslopes.

Parent Materials: Colluvium and residuum.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, parent materials tend to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, parent material tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including Ram Flat, Goat Flat, and Horse Ridge, parent materials tend to be migmatite and/or gneiss.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss, and migmatite.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, bedrock tends to be granodiorite of the Louis Lake Pluton.

In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, bedrock tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including Ram Flat, Goat Flat, and Horse Ridge, bedrock tends to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 82 to 86 cm.

Additional environment data summaries are provided in Table 9.

Potential natural vegetation

The potential natural vegetation of this ecological type is Ross' avens and blackroot sedge (Johnson and Billings 1962). Blackroot sedge is the projected climax species. Ross' avens occurs as a codominant with blackroot sedge; however, Ross' avens tends to be more general in its distribution than blackroot sedge, and, therefore, has less value as an indicator of this type. Blackroot sedge and Ross' avens form a dense, nearly continuous turf interrupted by cobbles, stones, and stone stripes. Common herbaceous species, including alpine sagebrush, cushion phlox, American bistort, lance-leaved stonecrop, dwarf clover, purple reedgrass, slender wheatgrass, Sandberg bluegrass, spike trisetum, and common woodrush, occur interlaced between Ross' avens and densely, caespitose patches of blackroot sedge. Table 10 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the GEROT-CAEL3 alpine turf, Agneston Family ET are deep with dark brown to black silt-rich upper horizons; yellowish-brown, moderately clayey (avg. 19%) subsurface horizons; and moderate amounts of coarse fragments (avg. 46%). A typical soil features an A/Bw/Bt horizonation. Diagnostic soil horizons include a silt-rich mollic (avg. 27 cm thick) or ochric (avg. 10 cm thick) epipedon, and a thick, argillic horizon (avg. 49 cm thick). Particle size class was loamy-skeletal. Soils were Typic Haplocryalfs [2], Inceptic Haplocryalfs [1], and Humic Dystrocryepts [1]. The relatively high degree of soil development typical of this ET is the result of an extremely long period of undisturbed weathering, particularly on high-level erosion surface remnants, combined with powerful mechanical weathering from the free-thaw cycle.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Typic Haplocryalfs

A—0 to 11 cm: very dark brown (10YR 2/2) very fine sandy loam, black (10YR 2/1), dry; 58% sand; 10% clay; moderate medium granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and few medium roots and many very fine roots; common fine and few medium and many very fine pores; 6% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 6.0; clear wavy boundary.

Bw—11 to 29 cm: dark yellowish brown (10YR 3/4) medium gravelly sandy loam, light yellowish brown (10YR 6/4), dry; 56% sand; 15% clay; weak, very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and few medium roots and many very fine roots; common fine and few medium and many very fine pores; 15% patchy distinct clay films on top surfaces of rock fragments; 8% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 24% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6; clear wavy boundary.

Bt1—29 to 78 cm: dark yellowish brown (10YR 4/4) very stony sandy loam, light yellowish brown (10YR 6/4), dry; 67% sand; 19% clay; weak medium subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and few medium roots and many very fine roots; common fine and few medium and many very fine pores; 2% patchy faint clay films between sand grains and 30% patchy distinct clay films on top surfaces of rock fragments; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 20% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 22% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6; clear wavy boundary.

2Bt2—78 to 102 cm: yellowish brown (10YR 5/4) extremely stony sandy loam, very pale brown (10YR 7/4), dry; 72% sand; 19% clay; weak fine subangular blocky structure, and weak very fine subangular blocky structure; very friable, soft, slightly sticky, slightly plastic; common fine roots and common very fine roots; common fine and common medium and common very fine pores; 4% patchy faint clay films between sand grains and 30% patchy distinct clay films on top surfaces of rock fragments; 15% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 19% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 41% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.6.

Ecology

Turf represents alpine plant communities with a more continuous coverage of plants and a lower percentage of rocks and erosion pavement at the soil surface than alpine fellfields (Johnson 2004). Similar to fellfields, turf communities are located on exposed slopes with little to no snow accumulation and experience strong winter winds and cold. However, turf communities occur in sites slightly less harsh and more sheltered than fellfields, allowing the vegetation to form a more continuous coverage. Blackroot sedge is densely caespitose sedge that is resilient to the cold, dry, windy conditions typical above timberline. Blackroot sedge occurs along a continuum from extremely windswept sites characterized by cushion plant communities to sheltered sites near timberline. However, blackroot sedge is most abundant at moderately exposed to partially sheltered sites with little to no snow accumulation typical of the GEROT-CAEL3 alpine turf, Agneston Family ET. Ross' avens is more general in its habitat preference than blackroot sedge, in part due to its ability to store large amounts of carbohydrates in roots and rhizomes (Mooney and Billings 1960). Ross' avens-blackroot sedge alpine turf vegetation has been described as "climax" vegetation in the Beartooth Mountains of northern Wyoming-southern Montana (Johnson and Billings 1962). Presumably, sites where this ecological type occurs have been stable for long time periods as evidenced by the high degree of development typical of soils in these communities. On high-level erosion surface remnants, this type is commonly associated with slopes experiencing various types of frost action, especially stone stripes, which are best expressed on slopes between 7 and 27% gradient (Richmond 1949). Wind deflation is at a minimum at these sites and is mitigated by the dense turf that creates a barrier against wind erosion.

Blackroot sedge has been characterized as a calcicole, or a plant species requiring calcareous substrates (Bamberg and Major 1968; Jones and Ogle 2000). However, this species is known to also occur on siliceous substrates throughout the Rocky Mountains, including in the GEROT-CAEL3 Alpine Turf, Agneston Family ET (Johnson and Billings 1962; Cooper and others 1997; Komárková and Webber 1978). The occurrence of blackroot sedge on non-calcareous substrates may, in part, be explained by eolian contributions to alpine soils of carbonate-rich silts from intermountain basins. Eolian contributions from intermountain basins to alpine soils have been reported on the western slope of the WRR (Dahms 1993, Dahms and Rawlins 1996), the Uinta Mountains in Utah (Bockheim and Koerner 1997), the Snowy Range Mountains of southeast Wyoming (Rochette and others 1988), and the Colorado Front Range (Litaor 1987). It is likely that eolian sedimentation from sediments arising in the Green River Basin occurs along the eastern slope of the WRR, especially given that the east slope is located on leeward side of the Continental Divide where eolian silts carried by westerly winds would settle out. The dense sod of alpine turf effectively traps a thin layer of snow and windblown sediments enriched in base cations, thus increasing the pH of alpine soils (Dahms 1993, Bockheim and Koerner 1997). The carbonate-rich silts would provide a base-rich environment and may help explain the occurrence of the calcicole species, blackroot sedge, on non-calcareous substrates in the Rocky Mountains. The phenomenon of eolian sedimentation may also help explain the preponderance of Mollic soils (high base saturation, silt-rich horizon) in alpine environments, where the carbonate rich silts would increase base saturation and accumulate in the upper soil horizons forming an organic-rich cap over sandy residual or colluvial soils.

Management considerations

This ecological type occurs almost entirely within wilderness boundaries. Trampling by hikers and pack- and grazing-animals is the most important management issue concerning the Ross' avens-blackroot sedge alpine turf, Agneston Family ET. This ecological type is tolerant of moderate trampling. However, heavy trampling that damages the turf will result in the extirpation of blackroot sedge and Ross avens and the initiation of wind erosion. Managers should encourage backpackers and wranglers to stay on maintained trails. When traveling off-trail, recreationists can mitigate the effects of trampling by (1) spreading out across the landscape, and (2) traveling on hard surfaces such as boulder, stone, or talus slopes whenever common sense and safety dictates. In the rare event of a fire in the alpine zone, it is assumed, given the dense sod created by these species and their ability to reproduce vegetatively, that post-fire response would be positive. Blackroot sedge is an important forage species for domestic sheep (Hermann 1970). Blackroot sedge is best grazed lightly, later in the season when it has completed most of its growth for the year and carbohydrate reserves are high.

Similar ecological types

Ecological Type 1

Type: Ross' avens Fellfield, McCall Family ET

Floristic differences: The two types differ floristically in that the McCall Family ET has little to no blackroot sedge and is characterized by discontinuous vegetation, erosion pavement, and abundant cushion plants, while the Agneston Family ET is characaterized by abundant blackroot sedge, and a more continuous vegetation cover.

Environmental differences: The two types differ environmentally in that the McCall Family ET is located on the most exposed, windswept sites that experience little to no snow accumulation, while the Agneston Family ET is located on slightly more sheltered sites that experience moderate snow accumulation. Secondly, the soils of the McCall Family (Inceptisols) are relatively low in clay when compared to soils in the Agneston Family ET (Alfisols).

Ecological Type 2

Type: Snow willow/Bellardi bog sedge, McCall Family ET

Floristic differences: The two types differ floristically in that the Agneston Family ET has little to no snow willow or Bellardi bog sedge and is characterized by abundant blackroot sedge.

Environmental differences: The two types differ environmentally in that Agneston Family ET is located on relatively more exposed, windswept sites that experience low to moderate amounts of snow accumulation, while the snow willow/Bellardi bog sedge, McCall Family ET is located on more sheltered sites that experience moderate to high snow accumulation and relatively abundant soil moisture throughout the year.

Table 9—Summary of environmental variables for the GEROT—CAEL3 Alpine Turf, Agneston Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,334	3,242	3,411
Slope (%)	22	20	25
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm/year)	839	816	855
Degree days	8,759	7,993	10,100
Frost-free days	15.5	15	16.4
Site water balance (mm)	-82	-94	-72
Average annual temperature (°C)	-1.6	-1.9	-1
Total annual potential evapotranspiration (mm)	371	348	384
Summer radiation (KJ)	19,910	19,180	20,800
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	46	39	54
Clay (% in particle size control section)	19	13	23
pH (in particle size control section)	5	4.7	5.5
Available water capacity (mm/m)	70	46	95
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil, < 2mm fraction (%)	0	0	0
Exposed bedrock	0	0	0
Gravel	0	0	0
Cobble	7	3	10
Stones	15	3	20
Boulders	4	1	5
Litter	24	20	35
Wood	0	0	0
Moss and lichen	4	2	5
Basal vegetation	44	35	60
Water	0	0	0

Table 10—Constancy/cover table for common plant species occurring in the GEROT - CAEL3 Alpine Turf, Agneston Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	Western yarrow	50	1	1	1
AGGL	*Agoseris glauca*	Pale agoseris	50	1	1	1
ANSES	*Androsace septentrionalis* var. *subulifera*	Pygmyflower rockjasmine	50	1	1	1
ANUM	*Antennaria umbrinella*	Umber pussy-toes	50	1	1	1
ARSC	*Artemisia scopulorum*	Alpine sagebrush	75	2	1	3
DRAU	*Draba aurea*	Golden draba	50	1	1	1
DRCA4	*Draba cana*	Cushion draba	50	1	1	1
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens	100	19	10	30
MIOB2	*Minuartia obtusiloba*	Twinflower sandwort	50	3	1	5
NONI	*Nothocalais nigrescens*	Meadow prairie-dandelion	50	1	1	1
PHPU5	*Phlox pulvinata*	Cushion phlox	100	2	1	5
POBI6	*Polygonum bistortoides*	American bistort	75	2	1	3
PODI2	*Potentilla diversifolia*	Varileaf cinquefoil	50	3	1	5
POGR9	*Potentilla gracilis*	Slender cinquefoil	50	3	3	3
POVI	*Polemonium viscosum*	Sticky polemonium	50	1	1	1
SARH2	*Saxifraga rhomboidea*	Diamondleaf saxifrage	50	1	1	1
SELA	*Sedum lanceolatum*	Lance-leaved stonecrop	75	2	1	3
SIKI	*Silene kingii*	King's campion	50	2	1	3
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	50	1	1	1
TRNA2	*Trifolium nanum*	Dwarf clover	75	4	1	5
Grasses:						
CAPU	*Calamagrostis purpurascens*	Purple reedgrass	100	2	1	3
ELEL5	*Elymus elymoides*	Squirreltail	50	2	1	3
ELTR7	*Elymus trachycaulus*	Slender wheatgrass	75	2	1	3
FEBR	*Festuca brachyphylla*	Alpine fescue	50	3	3	3
FESA	*Festuca saximontana*	Rocky Mountain fescue	50	4	3	5
POAR2	*Poa arctica*	Arctic bluegrass	50	3	1	5
POSE	*Poa secunda*	Sandberg bluegrass	100	6	1	15
TRSP2	*Trisetum spicatum*	Spike trisetum	75	2	1	3
Graminoids:						
CAAL6	*Carex albonigra*	Black-and-white-scaled sedge	50	1	1	1
CAEL3	*Carex elynoides*	Blackroot sedge	100	18	15	20
CAMA9	*Carex macloviana*	Falkland island sedge	50	1	1	1
CASC10	*Carex scirpoidea*	Canadian single-spike sedge	50	5	5	5
LUMU2	*Luzula multiflora*	Common woodrush	100	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Snow Willow/Bellardi Bog Sedge, McCall Family Ecological Type

Salix reticulata var. *nana*/*Kobresia myosuroides*, McCall Family ET

SAREN2/KOMY, McCall Family ET

N = 3

Distribution

The snow willow/Bellardi bog sedge, McCall Family Ecological Type occurs in the WRR along the continental divide within the alpine zone of Chapman and others (2004). This ET occurs from the upper Jakey's Fork, Grasshopper, Dinwoody, and Bull Lake Creek drainages in the Fitzpatrick Wilderness southeast to the upper North Fork of the Popo Agie River. This ET is a component of map unit 304L.

Environment

Aspect: North-northwest [2], northwest [1].

Landforms and Landscape Position: Solufluction terraces and lobes, avalanche paths, leeward slopes on alpine ridges, glacial cirques.

Parent Materials: Colluvium; colluvium over glacial till.

Bedrock: Precambrian porphyritic quartz monzonite, migmatite, gneiss.

In the North Fork Popo Agie and South Fork Little Wind River drainages, bedrock is porphyritic quartz monzonite. In the Grasshopper, Dinwoody, and Bull Lake Creek Drainages, bedrock is migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation is 81 to 86 cm.

Additional environment data summaries are provided in Table 11.

Potential Natural Vegetation

The potential natural vegetation of this ecological type is the Snow willow/Bellardi bog sedge habitat type. This habitat type has not previously been described. Snow willow and/or Hooker's mountain avens form a dense net-like shrub layer growing no taller than 5 to 6 cm. Bellardi bog sedge forms thick, tufted colonies punctuated by a variety of alpine forbs and graminoids. Ross' avens, alpine sagebrush, moss campion, manyray goldenrod, and arctic bluegrass are the most common and abundant herbaceous species. Tufted hairgrass is sometimes present in moist microsites. Northern fescue, a fescue species previously known to occur in the lower 48 states only in Glacier National Park, Montana, was found in this ecological type in the Fitzpatrick Wilderness (Massatti and Wells 2008). The documentation of northern fescue in the WRR represents a southern range extension for this species. Table 12 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the SAREN2/KOMY, McCall Family ET are deep with a low to moderate degree of soil development, moderately high coarse fragments (avg. 65%), and low to moderate clay (10–17%, avg. 13%). A thin (avg. 5 cm thick) organic horizon of partially decomposed sedge and grass roots may occur at the surface. A typical soil features an A/Bw/C horizonation. The C-horizons tended to be extremely gravelly. One soil featured a 41 cm thick Bt-horizon below the Bw-horizon. Diagnostic soil horizons include a mollic, umbric, or ochric epipedon (15 to 25 cm thick), and a cambic horizon (avg. 33 cm thick). Particle size class was loamy-skeletal. The soils were Typic Dystrocryepts [1], Mollic Haplocryalfs [1], and Humic Dystrocryepts [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Humic Dystrocryepts

A1—0 to 12 cm: black (10YR 2/1) very stony silt loam, black (10YR 2/1), dry; 35% sand; 13% clay; weak medium subangular blocky structure, and weak fine subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 2% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 5% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 49% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; strongly acid, pH 5.1; abrupt wavy boundary.

A2—12 to 23 cm: very dark grayish brown (10YR 3/2) very stony sandy loam, grayish brown (10YR 5/2), dry; 64% sand; 16% clay; weak coarse subangular blocky structure, and moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 8% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 36% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; abrupt wavy boundary.

Bw—23 to 52 cm: brown (10YR 4/3) extremely stony loamy coarse sand, light yellowish brown (2.5Y 6/3), dry; 82% sand; 8% clay; weak very fine subangular blocky structure, and weak fine subangular blocky structure; very friable, soft, nonsticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 16% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 29% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 30% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear wavy boundary.

2BC—52 to 79 cm: light olive brown (2.5Y 5/3) extremely gravelly sandy loam, light gray (2.5Y 7/2), dry; 73% sand; 13% clay; massive; very friable, loose, slightly sticky, nonplastic; many very fine and fine roots; many fine and many very fine pores; 21% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 43% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.9; clear wavy boundary.

2C—79 to 108 cm: pale olive (5Y 6/3) very gravelly loamy sand, light gray (5Y 7/2), dry; 84% sand; 9% clay; single grain; loose, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and many very fine pores; 8% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 33% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0.

Ecology

The snow willow/Bellardi bog sedge, McCall Family ET occurs intermediate between the Fellfield/Turf and Late snowbank vegetation along the exposure/moisture gradient in alpine environments. This ET tends to occur on north-facing, mesic, sheltered sites with low to moderate snow accumulations and was sometimes located downslope from late melting snowbanks. The continuous snow cover throughout the winter provides protection against winter desiccation, low temperatures, and physical abrasion by snow and ice particles typical of more exposed, snow-free alpine sites. When this ET is located downslope from late melting snowbanks, it may be considered a type of late snowbank vegetation as it benefits from a continual source of melt water throughout the summer months. Soil movement processes, including solufluction and soil creep, are often associated with these sites due to the constant source of water provided by late melting snowbanks. The vegetation in this ET is similar to alpine turf, with a more continuous coverage of plants and a lower percentage of rocks and erosion pavement than fellfield vegetation. However, the vegetation of this ET is more robust and productive than true alpine turf due to the more sheltered site conditions and abundance of soil moisture. Wind deflation is at a minimum at these sites and is mitigated by the dense turf that creates a barrier against wind erosion.

Bellardi bog sedge and Hooker’s mountain avens have been characterized as calcicoles, or plant species requiring calcareous substrates (Bamberg and Major 1968; Jones and Ogle 2000; Ladyman 2004c). However, both species are known to also occur on siliceous substrates throughout the Rocky Mountains, including in the SAREN2/KOMY, McCall Family ET (Johnson and Billings 1962; Cooper and others 1997; Komarkova and Webber 1978). The occurrence of Bellardi bog sedge and Hooker’s mountain avens on non-calcareous substrates may, in part, be explained by eolian contributions to alpine soils of carbonate rich silts from intermountain basins. Eolian contributions from intermountain basins to alpine soils have been reported on the western slope of the WRR (Dahms 1993; Dahms and Rawlins 1996), the Uinta Mountains in Utah (Bockheim and Koerner 1997), the Snowy Range Mountains of southeast Wyoming (Rochette and others 1988), and the Colorado Front Range (Litaor 1987). It is likely that eolian sedimentation from sediments arising in the Green River Basin occurs along the eastern slope of the WRR. This is especially pertinent given the fact that the east slope is located on the leeward side of the Continental Divide where eolian silts carried by westerly winds would settle out. The dense sod of alpine turf effectively traps snow and windblown sediments enriched in base cations, thus increasing the pH of alpine soils (Bockheim and Koerner 1997; Dahms 1993). The carbonate-rich silts would provide a base-rich environment and may help explain the occurrence of the calcicole species, Bellardi bog sedge and Hooker's mountain avens, on non-calcareous substrates in the Rocky Mountains. The phenomenon of eolian sedimentation may also help explain the preponderance of Mollic soils (high base saturation, silt-rich) in alpine environments, where the carbonate rich silts would increase base saturation and accumulate in the upper soil horizons forming an organic-rich cap over sandy residual or colluvial soils.

Management considerations

This ecological type occurs entirely within wilderness boundaries. Trampling by hikers and pack- and grazing-animals is the most important management issue concerning the snow willow/Bellardi bog sedge, McCall Family ET. This ecological type is tolerant of moderate trampling. However, heavy trampling that damages the sod and fragile willow stems will result in the extirpation of Bellardi bog sedge and snow willow and the initiation of wind and water erosion. Managers should encourage backpackers and wranglers to stay on maintained trails. When traveling off-trail, recreationists can mitigate the effects of trampling by (1) spreading out across the landscape, and (2) traveling on hard surfaces such as boulder, stone, or talus slopes whenever common sense and safety dictates. In the rare event of a fire in the alpine zone, it is assumed, given the dense sod created by these species and their ability to reproduce vegetatively, that post-fire response would be positive. Bellardi bog sedge and Hooker's mountain avens have been identified in the food caches of pikas (Johnson 1967; Ladyman 2004).

Similar ecological types

Ecological Type 1

Type: Ross' avens Fellfield, McCall Family ET

Floristic differences: The two types differ floristically in that the Ross' avens Fellfield, McCall Family ET has little to no snow willow or Bellardi bog sedge and is characterized by discontinuous vegetation, erosion pavement, and abundant cushion plants, while the snow willow/Bellardi bog sedge, McCall Family ET is characterized by a dense sod with abundant snow willow and Bellardi bog sedge.

Environmental differences: The two types differ environmentally in that the Ross' avens Fellfield, McCall Family ET is located on the most exposed, windswept sites that experience little to no snow accumulation, while the snow willow/Bellardi bog sedge, McCall Family ET is located on more sheltered sites that experience moderate to high snow accumulation and relatively abundant soil moisture throughout the year.

Ecological Type 2

Type: Ross' avens-blackroot sedge, Agenston Family ET

Floristic differences: The two types differ floristically in that the Agneston Family ET has little to no snow willow or Bellardi bog sedge and is characterized by abundant blackroot sedge.

Environmental differences: The two types differ environmentally in that Agneston Family ET is located on relatively more exposed, windswept sites that experience low to moderate amounts of snow accumulation, while the snow willow/Bellardi bog sedge, McCall Family ET is located on more sheltered sites that experience moderate to high snow accumulation and relatively abundant soil moisture throughout the year.

Table 11—Summary of environmental variables for the SAREN2/KOMY, McCall Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,305	3,251	3,384
Slope (%)	32	20	52
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	830	806	860
Degree days	9,009	8,525	9,298
Frost-free days	15.7	15.3	15.9
Site water balance (mm/year)	-53	-80	-19
Average annual temperature (°C)	-1.4	-1.6	-1.3
Total annual potential evapotranspiration (mm)	312	285	336
Summer radiation (KJ)	17,210	16,160	18,820
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	65	61	72
Clay (% in particle size control section)	13	10	17
pH (in particle size control section)	4.8	4.7	4.9
Available water capacity (mm/m)	60	38	77
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil, < 2mm fraction (%)	1	0	2
Exposed bedrock	0	0	0
Gravel	5	2	10
Cobble	5	5	5
Stones	6	3	10
Boulders	11	2	20
Litter	15	10	20
Wood	0	0	0
Moss and lichen	10	3	25
Basal vegetation	43	30	65
Water	0	0	0

Table 12—Constancy/cover table for common plant species occurring in the SAREN2/KOMY, McCall Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
DROCH3	*Dryas octopetala* var. *hookeriana*	Hooker's mountain avens	67	10	5	15
SAGLV	*Salix glauca* var. *villosa*	Grayleaf willow	67	4	3	5
SAREN2	*Salix reticulata* var. *nana*	Snow willow	100	13	5	25
Forbs:						
ARSC	*Artemisia scopulorum*	Alpine sagebrush	100	5	3	10
GEAL2	*Gentiana algida*	Whitish gentian	67	1	1	1
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens	100	15	10	20
HYGR5	*Hymenoxys grandiflora*	Graylocks four-nerve daisy	100	1	1	1
POBI6:	*Polygonum bistortoides*	American bistort	67	1	1	1
POGR9	*Potentilla gracilis*	Slender cinquefoil	67	3	3	3
POVI3	*Polygonum viviparum*	Viviparous knotweed	100	1	1	1
SECR	*Senecio crassulus*	Thickleaf ragwort	67	1	1	1
SIACS2	*Silene acaulis* var. *subacaulescens*	Moss campion	100	2	1	3
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	100	3	1	5
Grasses:						
FESA	*Festuca saximontana*	Rocky Mountain fescue	67	1	1	1
POAR2	*Poa arctica*	Arctic bluegrass	100	6	1	15
TRSP2	*Trisetum spicatum*	Spike trisetum	100	2	1	3
Graminoids:						
CASC10	*Carex scirpoidea*	Canadian single-spike sedge	67	2	1	3
KOMY	*Kobresia myosuroides*	Bellardi bog sedge	100	19	3	35
LUMU2	*Luzula multiflora*	Common woodrush	67	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Late Snowbank Vegetation, Hargran Family Ecological Type

Snowbank vegetation, Hargran Family ET

N = 7

Distribution

The late snowbank vegetation, Hargran Family Ecological Type occurs along the eastern slope of the WRR in the alpine zone ecoregion of Chapman and others (2004). The ecological type occurs near the Continental Divide from Union Peak and Goat Flat southeast to Wind River Peak and Atlantic Peak. It is a component of map unit 304L.

Environment

Aspect: North [1], north-northeast [1], northwest [1], south-southwest [2], west-northwest [1], west-southwest [1].

Landforms and Landscape Position: Solufluction terraces, frost hummocks, ground moraines in alpine glacial cirques, leeward slopes on alpine ridges.

Parent Materials: Colluvium over residuum; granitic glacial till.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, parent materials tend to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, parent material tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including Ram Flat, Goat Flat, and Horse Ridge, parent materials tend to be migmatite and/or gneiss.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss, and migmatite.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, bedrock tends to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, bedrock tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including Ram Flat, Goat Flat, and Horse Ridge, bedrock tends to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 79 to 89 cm.

Additional environment data summaries are provided in Table 13.

Potential natural vegetation

This ecological type includes a variety of alpine plant communities that inhabit late snowbank environments. Potential natural vegetation includes Parry's rush community type (Svalberg and others 1997), tufted hairgrass (Johnson and Billings 1962), willow/Holm's Rocky Mountain sedge, and grayleaf willow/tufted hairgrass (Jones and Ogle 2000). Table 14 provides a summary of species constancy and cover for the most common community types included in this ecological type.

Parry's rush community type: Parry's rush dominates a rich herbaceous community. Trace amounts of grayleaf willow or grouse whortleberry often occur on drier hummocks. Common forbs include alpine sagebrush, ballhead sandwort, subalpine fleabane, alpine daisy, tundra aster, American bistort, slender cinquefoil, and creeping sibbaldia. White marsh marigold may occur in slightly more moist microsites. Alpine timothy, Letterman's bluegrass, spike trisetum, Falkland island sedge, Raynold's sedge, and northern singlespike sedge are the most common graminoids.

Tufted hairgrass community type: Tufted hairgrass is the dominant herbaceous species. Tufted hairgrass cover varies depending on the duration and intensity of soil saturation. At the moist extreme, soils remain saturated to within 1 m of the soil surface throughout the summer, and tufted hairgrass forms a dense, nearly monocultural sward. At drier sites, soils are saturated for 20 to 30 days throughout the growing season, and tufted hairgrass cover is more diffuse. Species richness at drier sites tends to be greater than at wetter sites. Grayleaf willow is always present at low abundance, usually occurring on slightly drier microsites. Arctic willow may be present at high elevation sites, while alpine laurel may occur at sites closer to tree line. Common herbaceous species present at all sites include white marsh marigold, American bistort, varileaf cinquefoil, creeping sibbaldia, and Falkland island sedge. Herbaceous species common at drier sites include alpine sagebrush, subalpine fleabane, Ross' avens, arctic bluegrass, alpine fescue, Nelson's sedge, northern singlespike sedge, and common woodrush.

Willow/Holm's Rocky Mountain sedge community type: This community type features grayleaf willow or snow willow as the primary willow species. Snow willow occurs as a densely matted shrub often growing no more than 5 to 6 cm tall. Grayleaf willow is a low to moderately tall willow growing in small clumps. Arctic willow, another matted willow species, may also occur in this type. Holm's Rocky Mountain sedge dominates the herbaceous layer along with Ross' avens, alpine sagebrush, varileaf cinquefoil, Sandberg bluegrass, and Rocky Mountain pussytoes. Other herbaceous species include tundra aster, tufted hairgrass, coiled lousewort, alpine leafybract aster, three-hulled rush, and woolly fleabane.

Grayleaf willow/tufted hairgrass plant community: Grayleaf and planeleaf willows are found growing on frost hummocks. Engelmann spruce seedlings may occasionally occur on the frost hummocks. The herbaceous layer is relatively species rich despite being thin and scattered. Bare mineral soil and gravels are the most prevalent ground cover, the result of frost boils. Tufted hairgrass occurs mostly in the depressions in between the frost hummocks. Pioneer species, including twinflower sandwort, dwarf clover, wormleaf stonecrop, and moss campion, have gained a foothold on frost boils. Other herbaceous species include northern singlespike sedge, alpine bitterroot, Ross' avens, mountain bentgrass, Falkland island sedge, thickleaf ragwort, and Yellowstone whitlow-grass.

Soils

Soils in the late snowbank vegetation, Hargran Family ET are quite diverse depending on landform. Many of the soils in this ET featured the "Oxyaquic" subgroup. In general, oxyaquic soils are saturated within 1 m of the soil surface for 20 or more consecutive days or 30 or more cumulative days throughout the growing season, yet lack redoximorphic features typical of other semi- to permanently saturated soils.

Soils on solufluction terraces (see "Typical Pedon Description") are deep with a moderate degree of soil development, low to moderate coarse fragments (<40%), and low to moderately high clay (10–20%). A typical soil features an A-AB/Bw/Ab horizonation. The Ab-horizon results from the gradual burial of the soil surface due to solufluction of uphill soil material. Diagnostic soil horizons include an umbric epipedon (41 cm thick) and a cambic horizon (43 cm thick). Soils were loamy-skeletal, Oxyaquic Dystrocryepts.

Soils on frost-hummocks were deep with a moderate degree of soil development, high coarse fragments (>70%), and moderately high clay (18–25%). A typical soil features an A/Bw-Bt/C horizonation. Diagnostic soil horizons include an umbric epipedon (36 cm thick) and an argillic horizon (avg. 70 cm thick). Soils were loamy-skeletal Oxyaquic Haplocryalfs.

Soils on ground moraines in alpine glacial cirques were moderately deep and weakly developed with high coarse fragments (avg. 77%) and low clay (avg. 8%). A typical soil featured an A/Bw-Bt/C horizonation. The C-horizon was often times composed of interlocking boulders and stones within 100 cm of the soil surface. Diagnostic soil horizons include an ochric (avg. 10 cm thick) or umbric (18 cm thick) epipedon, and a cambic horizon (44 cm thick). Entisols were lacking a cambic horizon. One soil in the tufted hairgrass community type featured redoximorphic features within 31 cm of the soil surface and soil saturation within 100 cm of the soil surface throughout the growing season. Soils were loamy-skeletal Aquic Dystrocryepts, sandy-skeletal Oxyaquic Dystrocryepts, and fragmental Oxyaquic Cryorthents.

Soils on leeward slopes of alpine ridges were shallow to moderately deep to bedrock, high in coarse fragments (avg. 76%), and low in clay (avg. 12 %). Soils featured A/Bw/C/R horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 11 cm thick), a cambic horizon (19 cm thick), and lithic contact (avg. 56 cm depth). Entisols were lacking a cambic horizon. Soils were loamy-skeletal Lithic Dystrocryepts and sandy-skeletal Oxyaquic Cryorthents.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Oxyaquic Dystrocryepts

<u>A—0 to 16 cm</u>: very dark brown (10YR 2/2) loam, very dark grayish brown (10YR 3/2), dry; 44% sand; 10% clay; weak very fine subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and many very fine roots; common fine and common medium and common coarse and many very fine pores; 8% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0; clear wavy boundary.

<u>AB—16 to 41 cm</u>: very dark brown (10YR 2/2) very gravelly sandy loam, brown (10YR 4/3), dry; 54% sand; 14% clay; moderate medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 23% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 34% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; abrupt wavy boundary.

<u>Bw1—41 to 60 cm</u>: brown (10YR 4/3) gravelly sandy loam, yellowish brown (10YR 5/4), dry; 67% sand; 11% clay; weak coarse subangular blocky structure; friable, soft, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 65% patchy prominent silt coats on top surfaces of rock fragments; 2% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 28% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0; gradual wavy boundary.

<u>Bw2—60 to 84 cm</u>: dark brown (10YR 3/3) very gravelly sandy loam, yellowish brown (10YR 5/4), dry; 70% sand; 10% clay; weak medium subangular blocky structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and few medium roots and common very fine roots; common fine and few medium and common very fine pores; 29% patchy distinct silt coats on top surfaces of rock fragments; 6% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 31% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; abrupt smooth boundary.

<u>2ABb1—84 to 108 cm</u>: very dark grayish brown (10YR 3/2) sandy loam, brown (10YR 5/3), dry; 59% sand; 12% clay; weak very thick platy structure, and moderate medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common very fine roots; many very fine pores; 22% patchy prominent silt coats on top surfaces of rock fragments; 14% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear smooth boundary.

<u>2ABb2—108 to 115 cm</u>: dark brown (10YR 3/3) medium gravelly sandy loam, pale brown (10YR 6/3), dry; 62% sand; 14% clay; weak very thin platy structure, and moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; many fine and common very fine pores; 33% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8.

Ecology

A late snowbank environment is defined here as a section of land surface that is influenced by snow that has been redistributed by wind and accumulated in sheltered sites, either directly by physically covering the site, or indirectly by providing melt-water throughout the growing season. Redistribution and accumulation of snow in alpine environments is strongly influenced by slope aspect and the direction of the prevailing winds (Seppälä 2004). Secondary turbulence is created when wind encounters an obstacle, such as a mountain summit, ridgeline, or boulder, and snow carried by wind is deposited on the leeward side of the obstacle. Throughout the winter months, successive snowstorms, usually accompanied by strong winds, lead to the accumulation of snowbanks on the leeward side of obstacles.

Late snowbank vegetation, also called snowbed communities (Douglas and Bliss 1977) or snow-patch vegetation (Helm 1982), is defined here as an assemblage of plant species occurring in a late snowbank environment. Snow accumulation is closely associated with four important factors affecting vegetation: insulation from extreme winter temperatures and desiccation by strong winter winds; shortened growing season; a source of melt water; and soil movement, including solufluction, frost boils, and hummocks (Helm 1982). The accumulated snow melts slowly throughout the following summer providing a continuous source of water for plant communities located downslope and immediately beneath the snowbank. The result is a steep environmental gradient over a relatively small area (Johnson and Billings 1962). The alpine plant species associated with late snowbank environments are found at these sites because of the protection provided there against winter desiccation, low temperatures, and summer drought typical of alpine fellfield and turf communities (Billings and Bliss 1959). Alpine plant species growing beneath the snowbank are adapted to shortened growing season associated with the gradual melting of snow and exposure to sunlight throughout the summer.

Management considerations

This ecological type occurs almost entirely within wilderness boundaries. Trampling by hikers and pack- and grazing-animals is the most important management issue concerning the late snowbank vegetation, Hargran Family ET. The ecological type is tolerant of low levels of trampling. The cold, moist to wet soils are easily damaged by even moderate levels of trampling. Managers should encourage backpackers and wranglers to avoid traveling across late snowbank vegetation. The small areal extent of most of these communities should make avoiding them a relatively simple task. Trails should avoid this ET and be designed to stay on drier soils, including the GEROT-CAEL3 Alpine Turf, Agneston Family ET and the GEROT Turf, McCall Family ET. In trail building situations where avoiding this ET is logistically difficult, managers should consider armoring the trail with stones and cobbles across late snowbank environments. The vegetation of this ET is highly productive for grazing animals. These sites are best grazed at low levels later in the summer, after the soils have begun to dry.

Similar ecological types

Ecological Type 1

Type: Parry's rush, Oxyaquic Cryorthents ET

Floristic differences: The Parry's rush community type of the Hargran Family ET is the same as the Parry's rush community in the Oxyaquic Cryorthents ET.

Environmental differences: The two types differ environmentally in that the Hargran Family ET occurs above timberline, while the Parry's rush, Oxyaquic Cryorthents occurs at or slightly below timberline.

Ecological Type 2

Type: Oxyaquic soils, Elvick Family ET

Floristic differences: A number of vegetation types constitute the Oxyaquic soils, Elvick Family ET, including some of those listed under the Hargran Family ET.

Environmental differences: The two types differ environmentally in that the Hargran Family ET occurs above timberline and is associated with late snowbank environments, while the Oxyaquic soils, Elvick Family ET occurs in riparian zones and wetlands either above or below timberline.

Table 13—Summary of environmental variables for the Late Snowbank Vegetation, Hargran Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,306	3,167	3,505
Slope (%)	19	1	38
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	838	786	892
Degree days	8,839	7,316	10,130
Frost-free days	15.6	14.5	16.5
Site water balance (mm/year)	-117	-166	-33
Average annual temperature (°C)	-1.5	-2.2	-0.9
Total annual potential evapotranspiration (mm)	369	285	432
Summer radiation (KJ)	19,850	18,340	20,620
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	70	35	99
Clay (% in particle size control section)	12	4	22
pH (in particle size control section)	4.9	4.8	5.1
Available water capacity (mm/m)	41	13	75
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil, < 2mm fraction (%)	11	1	35
Exposed bedrock	2	0	10
Gravel	3	1	10
Cobble	4	1	10
Stones	9	2	15
Boulders	5	1	10
Litter	14	7	30
Wood	0	0	0
Moss and lichen	13	2	20
Basal vegetation	42	15	60
Water	0	0	0

Table 14. Constancy/cover table for common plant species occurring in the Late Snowbank Vegetation, Hargran Family ET.

			Tufted hairgrass C.T.				Parry's rush C.T.				Grayleaf willow/ Tufted hairgrass C.T.			
Characteristic	Species		Con	Cov	Min	Max	Con	Cov	Min	Max	Con	Cov	Min	Max
			Percent				*Percent*				*Percent*			
Shrubs:														
SAGLV	*Salix glauca* var. *villosa*	Grayleaf willow	100	2	1	3					100	18	10	25
Forbs:														
ARSC	*Artemisia scopulorum*	Alpine sagebrush					100	9	3	15	100	3	1	5
CALE4	*Caltha leptosepala*	White marsh marigold	100	1	1	1								
ERCO24	*Eremogone congesta*	Ballhead sandwort					100	1	1	1				
ERPES3	*Erigeron peregrinus* var. *scaposus*	Subalpine fleabane					100	8	5	10				
ERSI3	*Erigeron simplex*	Alpine daisy					100	3	1	5				
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens									100	9	3	15
ORAL4	*Oreostemma alpigenum*	Tundra aster					100	1	1	1				
POBI6	*Polygonum bistortoides*	American bistort	100	1	1	1	100	3	1	5	100	2	1	3
PODI2	*Potentilla diversifolia*	Varileaf cinquefoil	100	3	1	5					100	6	1	10
POGR9	*Potentilla gracilis*	Slender cinquefoil					100	2	1	3				
SIPR	*Sibbaldia procumbens*	Creeping sibbaldia	100	2	1	3	100	4	3	5				
Grasses:														
DECE	*Deschampsia cespitosa*	Tufted hairgrass	100	42	20	65	100	3	3	3	100	6	3	10
PHAL2	*Phleum alpinum*	Alpine timothy					100	4	3	5				
POLE3	*Poa lettermanii*	Letterman's bluegrass					100	2	1	3				
TRSP2	*Trisetum spicatum*	Spike trisetum					100	1	1	1				
Graminoids:														
CAMA9	*Carex macloviana*	Falkland island sedge	100	2	1	3	100	3	3	3				
CARA6	*Carex raynoldsii*	Raynolds' sedge					100	3	3	3				
CASC10	*Carex scirpoidea*	Canadian single-spike sedge				100	1	1	1					
JUPA	*Juncus parryi*	Parry's rush					100	25	20	30				

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Subalpine Fir Series

Principal Species Description

Subalpine fir

Abies lasiocarpa (Hook.) Nutt.

Subalpine fir is the smallest of the eight species of true firs native to the western United States (Uchytil 1991a). Subalpine fir is widely distributed across western North America, occurring along the Pacific Coast from central Yukon Territory and southeastern Alaska south along the eastern slope of the Coast Range in British Columbia to the Olympic Mountains in Washington, and along both slopes of the Cascade Mountains into southern Oregon (Alexander and others 1990). Subalpine fir is not found on the western slope of the Coast Range in southern British Columbia or along the Coast Range in Washington and Oregon; however, it does occur on Vancouver Island. In the Rocky Mountains, subalpine fir occurs continuously along the continental divide from latitude 55° N in British Columbia and Alberta south through the Rocky Mountains of Montana, Oregon, Idaho, and Wyoming. In Wyoming, the distribution of subalpine fir is discontinuous south and southeast of the Wyoming, Salt River, and WRRs, picking up again in northeastern Utah in the Bear River, Wasatch, and Uinta Mountains, in southeastern Wyoming in the Snowy and Laramie Ranges, and in the Rocky Mountains of central Colorado. In southern Utah, Arizona, and western New Mexico, the distribution of subalpine fir is disjointed and limited to the highest elevations.

In British Columbia and Alberta subalpine fir occurs at elevations between 914 and 2,134 m, but it is most abundant above 1,524 m (Alexander and others 1990). In the northern Rocky Mountains, including mountain ranges in Montana, Idaho, and eastern Oregon and Washington, subalpine fir occurs most commonly between 1,524 and 2,743 m and occasionally down to 610 m especially in cold air drainages and north-facing slopes. Average temperatures in the subalpine fir zone of the northern Rocky Mountains in January and July range from -15 to -9 °C and 7 to 13 °C, respectively. Average annual precipitation ranges between 610 and 1,520 mm.

In the central Rocky Mountains, including mountain ranges in Colorado, Wyoming, and northern Utah, subalpine fir occurs most commonly at elevations between 2,743 m and timberline (3,200–3,500 m) and as low as 2,438 m strictly in cold air drainages and on north-facing slopes (Alexander and others 1990). Average temperatures in the subalpine fir zone of the central Rocky Mountains in January and July range between -12 to -9 °C and 10 to 13 °C, respectively. Average annual precipitation ranges between 610 and 1,520 mm.

In the southern Rocky Mountains, including mountain ranges in New Mexico, Arizona, southern Utah, subalpine fir is restricted primarily to north-facing slopes at elevations between 2,896 and 3,353 m (Alexander and others 1990). Average temperatures in the subalpine fir zone of the southern Rocky Mountains in January and July range between -9 to -7 °C and 10 to 16 °C, respectively. Average annual precipitation ranges between 610 and 1,020 mm.

Subalpine fir is tolerant of a variety of soil types and condition, including soils derived from sandstone, sandy-shale, limestone, dolomite, granite, basalt, tuff, shale and siltstone, breccia, andesite, glacial till, sandy alluvium, and deep volcanic ash (Pfister and others 1977; Youngblood and Mauk 1985; Johnson and Simon 1987; Svalberg and others 1997; Johnson and others 2001). Subalpine fir potential is limited on shallow and coarse-textured soils developed from granitic and schistic rocks, conglomerates, coarse sandstones, and permanently saturated soils (Alexander and others 1990). Subalpine fir can tolerate short-term soil saturation and is commonly found growing in moist alluvial forests, along seeps and springs, and on stream terraces, floodplains, and wetland margins (Hansen and others 1995; Kovalchik and Clausnitzer 2004; Wells 2006).

Subalpine fir is a monoecious species with male cones on the lower branches of the crown and female cones positioned upright on the crowns upper branches (Alexander and others 1990). Subalpine fir may begin to produce seed when trees are 1.2 to 1.5 m tall and 20 years old; however, seed production is delayed in closed canopy situations. Pollination occurs by wind-dissemination in late spring and early summer. The conspicuous, upright purple-indigo blue cones open in mid-August to mid-September, and seeds ripen from mid-September to late-October. Along the Pacific Coast and in the northern Rocky Mountains, subalpine fir produces good (20–49 cones/tree) to heavy crops (50–99 cones/tree) every three years, interspersed with light crops to failures the other two years. In the central and southern Rocky Mountains seed production is relatively poor with infrequent heavy crops and many more failures. When subalpine fir cones are ripe, the scales fall away with the large winged seeds and the cones disintegrate on the tree (Alexander and others 1990). Subalpine fir seeds are wind dispersed, and the dispersal pattern is strongly related to the direction of the prevailing winds.

Subalpine fir seedlings thrive on a variety of substrates and under nearly all levels of light intensity. However, establishment and early survival are usually favored by at least partial shade (Alexander and others 1990). In the Pacific Northwest, where subalpine fir co-occurs with Pacific silver fir, grand fir, and mountain hemlock, subalpine fir is considered less shade tolerant than the other species. In the central and southern Rocky Mountains, subalpine fir is the most shade tolerant tree species and is considered climax vegetation. In more open canopy situations, subalpine fir is not a successful competitor with Engelmann spruce, lodgepole pine, or Rocky Mountain Douglas-fir when light intensity exceeds 50% of full shade. Subalpine fir commonly reproduces vegetatively through a process termed “layering.” Layering refers to the process of tree stems, which typically grow vertically, growing horizontally instead. New stems arise as the layering branches closest to the ground eventually become buried in litter and sprout roots. Layering is negligible in closed canopy situations and is most important under open canopies and near timberline.

Subalpine fir trees are extremely slow growing, and trees 25 to 51 cm in diameter typically are 150 to 200 years old under closed forest canopies (Alexander and others 1990). Trees greater than 250 years old are not uncommon but are extremely susceptible to heart-rot and, for this reason, do not live much beyond this age. The typical growth-form of subalpine fir across much of its geographic distribution is a narrow, cone-, or bullet-shaped crown standing 18 to 30 m tall (Uchytil 1991a). Near timberline, the growth-form of subalpine fir appears much like a flag in a stout wind, with the only living branches on the leeward side of the tree. Individual stems arise from a dense, layered mat and do not reach heights greater than 4 to 5 m due to severe winds and cold temperatures. Above tree line, subalpine fir features a krummholtz form, growing in dwarf, shrub-like mats no greater than 1 m tall.

Subalpine fir is very sensitive to fire, due to thin, resin-pocketed bark and shallow root systems and is killed or severely injured from even low intensity burns (Uchytil 1991a). At dry, lower elevation sites in the Rocky Mountains, fires occur more frequently and at lower intensity, with mean fire return intervals ranging between 17 and 28 years in western Montana to 80 to 100 years in central Wyoming and Colorado. The frequent fires kill subalpine fir and help maintain seral Douglas-fir or lodgepole pine forests at these sites. Moist, high elevation sites experience infrequent (>100 years), high intensity, stand-replacing burns. The tendency of subalpine fir-dominated stands to produce stand replacing burns is due to a combination of high fuel loads, highly flammable foliage, the long retention time of dead branches on the lower stem, and a tendency to grow in dense stands (Uchytil 1991a). Following fire, subalpine fir readily establishes on bare mineral soil from seed provided by individuals surviving in nearby unburned areas.

The western spruce budworm (*Choristoneura occidentalis*) and western balsam bark beetle (*Dryocoetes confusus*) are the two most common insect pests of subalpine fir in the spruce-fir region of the Rocky Mountains (Alexander and others 1990). The western spruce budworm feeds on buds, needles, cones, and seeds of trees of all ages, often resulting in severe defoliation (Hagle and others 2003). Following several years of heavy defoliation, branch dieback, top kill, and tree mortality can occur. Western balsam bark beetle feed on the phloem layer of the inner bark. Trees not killed directly by the bark beetles usually succumb to blue stain fungi, which the trees become inoculated with following attack. Wood borers, including longhorned beetles (Family: Cerambycidae) and metallic wood borers (Family: Buprestidae), may also attack subalpine fir. Longhorned beetles and metallic wood borers rarely kill their hosts; they usually only attack weakened and recently downed trees. Subalpine fir may suffer significant loss of growth and vigor from fir broom rust (*Melampsorella caryophyllacearum*). Subalpine fir is also susceptible to a variety of wood rotting fungi, which weaken trees and predispose them to windthrow and breakage by wind (Alexander and others 1990).

In the Rocky Mountains, the appropriate timber harvesting methods favoring subalpine fir over Engelmann spruce, lodgepole pine, and Douglas-fir include shelterwood and individual tree selection (Uchytil 1991a). The seed tree method is not generally recommended because of the susceptibility of subalpine fir to windthrow. Uneven-aged silviculture can be problematic because residual subalpine fir trees damaged during thinning operations are susceptible to attack by decay fungi. Light surface fires can be used following timber harvest as a management tool to remove subalpine fir seedlings at dry, lower elevation sites where subalpine fir is not a preferred timber species and to encourage the growth of Rocky Mountain Douglas-fir or lodgepole pine.

Subalpine fir forests are often unproductive as forage sites for livestock, and the palatability of subalpine fir to livestock and wild ungulates is generally low (Uchytil 1991a). However, moose and mountain goats may browse subalpine fir during the winter and spring. Subalpine fir forests provide important summer range for mule deer, elk, and black and grizzly bears. Snowshoe hare, flying squirrels, red squirrels, pine marten, lynx, and a variety of rodents inhabit subalpine fir forests. A number of bird species nest and feed in subalpine fir forests, including several woodpecker species, flycatchers, kinglets, nuthatches, juncos, thrushes, chickadees, crossbills, pine siskin, owls, and grouse. Red squirrels cache significant amounts of subalpine fir seeds in large middens across the forest floor. Chickadees, nuthatches, crossbills, pine siskin, and Clark's nutcracker forage on the seeds by physically removing them from the cones. Subalpine fir seeds are an important part of the diet of small birds because they are relatively large, comprising approximately 26% of the total weight of a cone. Lastly, blue grouse feed on the needles and buds of subalpine fir.

Subalpine Fir/Gooseberry Currant, Elting Family Ecological Type

Abies lasiocarpa/Ribes montigenum, Elting Family Ecological Type

ABLA/RIMO2, Elting Family ET

N = 2

Distribution

The subalpine fir/gooseberry currant, Elting Family Ecological Type, occurs in the WRR near the Continental Divide within the alpine zone of Chapman and others (2004). It is a component of map unit 304L.

This ET occurs at or near timberline on the boundary between alpine meadows and subalpine forests. These forested stands occur in scattered patches or "tree islands" separated from one another by sections of alpine meadow vegetation (Marr 1977). This ET typically occurs in microsites suitable for the establishment of tree seedlings, including gentle concavities and sheltered slopes. Trees in these forested stands are stunted from extreme cold temperatures and strong winds.

Environment

Aspect: West [1], west-northwest [1].

Landforms and Landscape Position: Backslopes and footslopes.

Parent Materials: Colluvium over residuum.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, parent materials tend to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, parent material tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including the areas surrounding Burro Flat, Horse Ridge, Brown Cliffs, and Dennis Lake, parent materials tend to be migmatite and/or gneiss.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss, and migmatite.

In the southern portion of the WRR near Atlantic Peak, Roaring Fork Mountain, and Wind River Peak, bedrock tends to be granodiorite of the Louis Lake Pluton.

In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, bedrock tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including the areas surrounding Burro Flat, Horse Ridge, and Brown Cliffs, and Dennis Lake, parent materials tend to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 80 to 83 cm.

Additional environment data summaries are provided in Table 15.

Potential natural vegetation

The potential natural vegetation of this ecological type is the subalpine fir/gooseberry currant habitat type whitebark pine phase (Steele and others 1983). Trees in these forested stands are stunted from extreme cold temperatures and strong winter winds. Subalpine fir and whitebark pine are the projected climax tree species. Whitebark pine is usually the dominant overstory tree species. Stunted subalpine fir and Engelmann spruce is typically found in the understory canopy layer.

Gooseberry currant and willows, including planeleaf and grayleaf, are the only shrub species present. Occasionally, on drier microsites at lower elevations near contiguous subalpine forests, grouse whortleberry may occur.

Overall, the herbaceous layers of the sites sampled were incredibly species rich; however, the spatial distribution of species depends on the location to the leeward, in the middle of, or to the windward of the tree islands. In the middle of the tree island, beneath the tree canopy, the herbaceous layer is depauperate and species richness is low. Species typical of the middle of these tree islands include Wheeler's bluegrass, Ross' sedge, long-leaved fleabane, and Rocky Mountain pussytoes. Species typical of the dry, windward side of the tree islands include Ross' avens, American bistort, slender cinquefoil, spiny milkvetch, twinflower sandwort, alpine bitterroot, spike woodrush, and northern singlespike sedge. Tufted hairgrass, tall fringed bluebells, spike trisetum, and Holm's Rocky Mountain sedge are typical of the moist, leeward side of the tree islands. Summaries of species constancy/cover and stand characteristics are provided in Tables 16 and 17, respectively.

Soils

Soils in the ABLA/RIMO2, Elting Family ET were moderately deep and deep with a low degree of soil

development, high coarse fragments (avg. 72%), and low clay (avg. 10%). A typical soil features an A/Bw/C/Cr-R horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 9 cm thick), a cambic horizon (23 cm thick), and paralithic or lithic contact (avg. 76 cm depth). Particle size class was sandy-skeletal. The soils were Typic Dystrocryepts and Typic Cryorthents.

Typical pedon description

Soil Classification: Sandy-skeletal, mixed, Typic Dystrocryepts

A—0 to 5 cm: very dark brown (10YR 2/2) fine gravelly fine sandy loam, dark grayish brown (10YR 4/2), dry; 62% sand; 18% clay; weak very fine granular structure; very friable, soft, slightly sticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 18% 2- to 5-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.1, Bromcresol green; abrupt wavy boundary.

Bw—5 to 28 cm: dark yellowish brown (10YR 4/4) fine gravelly sandy loam, light yellowish brown (10YR 6/4), dry; 72% sand; 14% clay; weak fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 21% 2- to 5-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8, Bromcresol green; clear smooth boundary.

C1—28 to 49 cm: brown (7.5YR 4/4) extremely gravelly loamy sand, reddish yellow (7.5YR 6/6), dry; 82% sand; 9% clay; moderate fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 11% 76- to 250-mm unspecified fragments and 52% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9, Bromcresol green; clear smooth boundary.

C2—49 to 70 cm: light yellowish brown (10YR 6/4) extremely cobbly coarse sand, brownish yellow (10YR 6/6), dry; 94% sand; 3% clay; weak fine granular structure, and weak fine subangular blocky structure; loose, nonsticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 11% 251- to 600-mm unspecified fragments and 37% 76- to 250-mm unspecified fragments and 38% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8, Bromcresol green; clear smooth boundary.

Cr—70 to 101 cm: brown (10YR 5/3) extremely bouldery coarse sand, very pale brown (10YR 7/3), dry; 93% sand; 5% clay; single grain; loose, nonsticky, nonplastic; few fine roots and few very fine roots; few fine and few very fine pores; 19% 76- to 250-mm unspecified fragments and 20% 2- to 75-mm unspecified fragments and 41% 601- to 3,000-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8, Bromcresol green.

Ecology

Three distinct morphological forms of trees are associated with the transition between subalpine forests and alpine tundra environments (Grant and Mitton 1977). The morphological forms are related to specific micro-environmental conditions associated with increasing elevation and wind exposure. The “spire” form is associated with trees in subalpine forests. This is the typical tree growth-form with a central stem and radiating branches. The “flagged” growth-form features short, erect stems appearing much like a flag in a stout wind, with the only living branches on the leeward side of the tree. This growth-form is typical of the transition zone between subalpine forest and alpine tundra. Lastly, the krummholz or “elfinwood” growth-form features a shrub-like appearance with semi-erect to prostrate stems. The three growth-forms include a variety of intergrades making it difficult at times to distinguish between each. The flagged growth-form is most typical of trees in the ABLA/RIMO2, Elting Family ET.

Scientific evidence exists that these tree islands are actually mobile and that the trees move in the direction of the wind (Marr 1977). Branches on the windward side of the tree island die due to desiccation from strong winds or abrasion from blowing snow and ice, while leeward branches, protected from the wind by the dead branches of their own stems, continue to grow (Hadley and Smith 1983). Through a process called layering, tree stems, which typically grow vertically, begin to grow horizontally (Marr

1977). New stems arise as the layering branches closest to the ground eventually become buried in litter and sprout roots. Once the new stems grow to a height where they are affected by the wind, the process begins anew as the windward branches are killed and leeward branches begin to layer in the direction of the wind. In this way, tree islands slowly move across the landscape in the direction of the wind.

Size and survival of tree islands are strongly interrelated (Marr 1977). In order for the tree islands to survive, leeward growth must exceed windward mortality. However, a delicate balance exists between the rate of leeward growth and windward mortality. If growth exceeds mortality to the point where the tree island increases in size, it is at risk of an outbreak of the black-felt fungus (*Herpotrichia nigra* Hartig). Larger tree islands create a stronger leeward eddy and a larger, deeper leeward snowdrift. The black-felt fungus is adapted to growth in a mixture of ice and liquid water near the freezing point, conditions common in alpine environments in late spring and early summer (Simms 1967). Individual trees buried by leeward snowdrifts are at risk of parasitism by the black-felt fungus. Leeward mortality is the result, and the life expectancy of the tree island is generally limited. Snowdrift mortality of trees on the leeward side of tree islands is also related to growing season length and the physiological demands of tree seedlings. The deeper the leeward snowdrift, the longer it takes for the snowdrift to melt the following summer, and the shorter the growing season for buried tree seedlings. This shortening of the growing season may result in death to buried tree seedlings that may not have enough time to store adequate carbohydrate reserves to survive the following winter.

The mechanisms responsible for leeward mortality of tree islands also play a role in the spacing of tree islands (Marr 1977). Two or more tree islands separated by gaps will commonly occur in a line parallel to the direction of the wind. The size of the gap between two tree islands corresponds to the size and depth of leeward snowdrifts.

Succession

An initial herbaceous/shrub stage (A) follows a stand-replacing disturbance (Bradley and others 1992). Stage (A) may be held in place for extended time periods depending on post-disturbance conditions at the site. A conifer seedling stage (B) follows the initial herbaceous/shrub stage. During stage (B), whitebark pine germinates from seeds cached at the disturbed site by Clark’s nutcrackers, and subalpine fir and Engelmann spruce seedlings grow in the shelter of shrubs and whitebark pine seedlings. A mature whitebark pine, subalpine fir, Engelmann spruce stand (C) develops in approximately 75 to 100 years following stage (B). Two to three centuries may be required for the climax stand (D) to develop. Low severity fires at stages (A) through (D) maintain the stand at each respective stage, while severe fire will completely reset the successional pathway.

Management considerations

Traditional management issues important in montane and subalpine forests, including timber harvest and prescribed fire, are of little importance in these high elevation forests that occur almost exclusively within wilderness boundaries. Forest fire is rare in these high elevation forests; however, it can occur due to lightning strike or as large high intensity fires invade from lower elevation forests (Bradley and others 1992). Physical disturbance due to avalanches, snow and wind abrasion, or rockslide more commonly destroy these stands and reset the successional pathway. Gooseberries (*Ribes* spp.) are an obligate alternate host of white pine blister rust. Whitebark pine in these stands may be at increased risk of white pine blister rust, especially under future climate warming. Also, sickletop lousewort (*Pedicularis racemosa*), a species recently discovered to be an alternate host of white pine blister rust (McDonald and others 2006), was found in this ecological type. See the “Principal Species Description” for whitebark pine for more details regarding management considerations for this newly discovered host.

The ABLA/RIMO2, Elting Family ET has high aesthetic, watershed, and wildlife value. The snow trapped in drifts on the leeward side of this ET melt slowly throughout the summer months, providing a steady source of water for the streams and rivers down valley. Also, these small forest stands provide one of the only forms of refuge for large mammals foraging in nearby alpine meadows and are home to numerous songbirds and small mammals.

Similar ecological types

Ecological Type 1

<u>Type</u>: Subalpine fir/gooseberry currant, Cranbay Family ET

<u>Floristic differences</u>: The two types differ floristically in that the Elting Family ET has whitebark pine as a significant part of the overstory, while the Cranbay family does not. Also, the trees in the Elting Family ET feature a flagged growth-form and occur in tree islands, whereas the trees in the Cranbay Family ET feature a spire growth-form and occur as contiguous forest.

<u>Environmental differences</u>: The two types differ environmentally in that the Elting Family ET occurs at or slightly above timberline, whereas the Cranbay Family ET generally occurs below timberline.

Ecological Type 2

<u>Type</u>: Krummholz, Klootch Family ET

<u>Floristic differences</u>: The two types differ floristically in that the trees in the Elting Family ET feature a flagged growth-form, whereas the trees in the Klootch Family ET most often feature a krummholz growth-form. However, the flagged growth-form may occur at lower elevations in the Klootch Family ET, in which case the two Ecological

Types differ in the absence of gooseberry currant in the Klootch Family ET.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at or slightly above timberline, whereas the Klootch Family ET occurs at higher elevations above timberline near the physiological limits of tree growth.

Table 15—Summary of environmental variables for the ABLA/RIMO2, Elting Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,238	3,207	3,268
Slope (%)	25	21	28
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	817	801	833
Degree days	9,545	9,306	9,784
Frost-free days	16.1	15.9	16.3
Site water balance (mm/year)	-117	-122	-113
Average annual temperature (°C)	-1.2	-1.3	-1.1
Total annual potential evapotranspiration (mm)	354	351	357
Summer radiation (KJ)	18,470	18,120	18,810
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	72	66	78
Clay (% in particle size control section)	10	7	12
pH (in particle size control section)	4.9	—	—
Available water capacity (mm/m)	28	23	33
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	4	3	5
Exposed bedrock	2	1	3
Gravel	2	1	3
Cobble	2	1	3
Stones	2	1	3
Boulders	8	6	10
Litter	20	10	30
Wood	3	1	5
Moss and lichen	7	2	12
Basal vegetation	50	30	70
Water	0	0	0

Table 16—Constancy/cover table for common plant species occurring in the ABLA/RIMO2, Elting Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	Whitebark pine	100	8	5	10
PIEN	*Picea engelmannii*	Engelmann spruce	100	8	5	10
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	10	5	15
PIAL	*Pinus albicaulis*	Whitebark pine	100	6	5	7
PIEN	*Picea engelmannii*	Engelmann spruce	100	4	3	5
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	4	1	7
PIAL	*Pinus albicaulis*	Whitebark pine	100	5	5	5
PIEN	*Picea engelmannii*	Engelmann spruce	100	1	1	1
Shrubs:						
RIMO2	*Ribes montigenum*	Gooseberry currant	100	5	3	7
SAPL2	*Salix planifolia*	Planeleaf willow	100	4	1	7
Forbs:						
ANME2	*Antennaria media*	Rocky Mountain pussytoes	100	4	3	5
ARSC	*Artemisia scopulorum*	Alpine sagebrush	100	4	3	5
ERCO5	*Erigeron corymbosus*	Long-leaved fleabane	100	4	3	5
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens	100	2	1	3
MEAL7	*Mertensia alpina*	Alpine bluebells	100	1	1	1
POBI6	*Polygonum bistortoides*	American bistort	100	4	3	5
POGR9	*Potentilla gracilis*	Slender cinquefoil	100	4	1	7
Grasses:						
POCU3	*Poa cusickii*	Cusick's bluegrass	100	4	3	5
TRSP2	*Trisetum spicatum*	Spike trisetum	100	1	1	1
Graminoids:						
CASC10	*Carex scirpoidea*	Northern singlespike sedge	100	3	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 17—Stand characteristics for the ABLA/RIMO2, Elting Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
ABLA	4.6	2.3–6.9	7.6	5.8–9.4	1,114	371–1,857
PIAL	2.3	—	10.4	9.7–11.2	274	235–314
PIEN	5.7	2.3–9.2	13.7	6.4–29.0	921	726–1,119

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
ABLA	9.1	—	53
PIAL	9.7	1.8	55
PIEN	6.4	—	45

Subalpine Fir/Grouse Whortleberry, McCall Family Ecological Type

Abies lasiocarpa/Vaccinium scoparium,
McCall Family Ecological Type

ABLA/VASC, McCall Family ET

N = 7

Distribution

The subalpine fir/grouse whortleberry, McCall Family Ecological Type, occurs within the granitic subalpine zone of Chapman and others (2004). This ET occurs along the upper extent of all of the major drainages in the study area, including Jakeys Fork, East Fork Torrey Creek, Dinwoody Creek, Dry Creek, Bull Lake Creek, South Fork Little Wind River, North Fork Popo Agie River, and the Middle Fork Popo Agie River. This ET is a component of map unit 327S.

Environment

Aspect: East [1], north [3], northwest [1], west-northwest [1], west-southwest [1].

Landforms and Landscape Position: Lateral moraines. Backslopes and footslopes.

Parent Materials: Granitic glacial till, granitic colluvium over granitic glacial till.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite.

In the Middle Fork Popo Agie drainage, bedrock is primarily granodiorite of the Louis Lake Pluton; however, pockets of gneiss do occur as well. In the North Fork Popo Agie and South Fork Little Wind River drainages, bedrock is porphyritic quartz monzonite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 66 to 79 cm.

Additional environment data summaries are provided in Table 18.

Potential natural vegetation

The potential natural vegetation for this ecological type is the subalpine fir/grouse whortleberry habitat type grouse whortleberry phase or whitebark pine phase (Steele and others 1983). Although subalpine fir is the projected climax dominant, the species rarely dominated the sample sites. The whitebark pine phase represents the cooler, upper elevations of the subalpine fir/grouse whortleberry habitat type. In the whitebark pine phase, whitebark pine and Engelmann spruce are codominant. Lodgepole pine is often codominant with subalpine fir in the grouse whortleberry phase. The grouse whortleberry phase represents the warmer, lower elevation range of the subalpine fir/grouse whortleberry habitat type. The first distinguishing characteristic of this habitat type is the incredibly strong regeneration of subalpine fir in the understory canopy layers, which far surpasses all other tree species. The second distinguishing characteristic of this habitat type is the thick cover of grouse whortleberry and sparse herbaceous layer. Heartleaf arnica and Ross' sedge are the only herbaceous species occurring with any consistency. Summaries of species constancy/cover and stand characteristics are provided in Tables 19 and 20, respectively.

Soils

The soils in this ET are relatively young as they are derived from Pinedale age glacial till deposited between 22,000 and 15,000 years ago (Dahms 2004b; Dahms, D.E., pers. comm.). Soils in the ABLA/VASC, McCall Family ET were moderately deep and deep with a low degree of soil development, variable amounts of rock fragments (35–94%, avg. 66%), and low clay (avg. 11%). A thin (avg. 6 cm thick) litter layer occurs at the surface. A typical soil features an A/Bw/C-Cd horizonation. Some soils may feature an E-horizon (avg. 14 cm thick) directly below, or in place of, an A-horizon. One soil featured a thick, dense layer of compacted glacial till (Cd-horizon) between 73 and 102 cm below the soil surface. Diagnostic soil horizons include an ochric epipedon (16 cm thick) and a cambic horizon (avg. 45 cm thick). One soil featured a 32-cm thick umbric epipedon. Particle size class included loamy-skeletal [5], sandy-skeletal [1], and fragmental [1]. Soils were Typic Dystrocryepts [5], Humic Dystrocryepts [1], and Typic Cryorthents [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Humic Dystrocryepts

Oi—0 to 1 cm: slightly decomposed plant material; clear wavy boundary.

Oe—1 to 7 cm: moderately decomposed plant material; clear smooth boundary.

A—7 to 22 cm: very dark grayish brown (10YR 3/2) cobbly silt loam, brown (10YR 4/3), dry; 24% sand; 13% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common fine roots and many medium roots and many coarse roots and many very coarse roots and common very fine roots; common fine and many medium and many coarse and many very coarse and common very fine pores; 5% 2- to 75-mm unspecified fragments and 13% 76- to 250-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; clear wavy boundary.

BA—22 to 32 cm: dark brown (10YR 3/3) very stony silt loam, brown (10YR 5/3), dry; 32% sand; 15% clay; moderate very coarse subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and many medium roots and common coarse roots and common very fine roots; common fine and many medium and common coarse and common very fine pores; 12% 2- to 75-mm unspecified fragments and 13% 76- to 250-mm unspecified fragments and 16% 251- to 600-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; clear wavy boundary.

2Bw1—32 to 55 cm: dark yellowish brown (10YR 4/6) very stony sandy loam, brownish yellow (10YR 6/6), dry; 63% sand; 13% clay; moderate coarse subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, nonsticky, nonplastic; common fine roots and common medium roots and few very fine roots; common fine and common medium and common coarse and common very fine pores; 13% 76- to 250-mm unspecified fragments and 16% 2- to 75-mm unspecified fragments and 22% 251- to 600-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; clear wavy boundary.

2Bw2—55 to 73 cm: dark yellowish brown (10YR 4/4) stony sandy loam, light yellowish brown (10YR 6/4), dry; 68% sand; 12% clay; weak medium subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots; common fine and common medium pores; 10% 2- to 75-mm unspecified fragments and 12% 76- to 250-mm unspecified fragments and 12% 251- to 600-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; abrupt smooth boundary.

2Cd1—73 to 91 cm; brown (10YR 5/3) very bouldery coarse sandy loam, very pale brown (10YR 7/4), dry; 69% sand; 12% clay; massive firm, moderately hard, very weakly cemented, slightly sticky, nonplastic; few medium roots; common fine and common medium and common coarse pores; 4% 76- to 250-mm unspecified fragments and 14% 251- to 600-mm unspecified fragments and 18% 2- to 75-mm unspecified fragments and 20% 601- to 3,000-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; abrupt smooth boundary.

2Cd2—91 to 102 cm: pale brown (10YR 6/3) very bouldery loamy coarse sand, very pale brown (10YR 7/3), dry; 82% sand; 6% clay; massive; very firm, hard, weakly cemented, nonsticky, nonplastic; 17% 2- to 75 mm unspecified fragments and 20% 601- to 3,000-mm unspecified fragments and 21% 251- to 600-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8.

Ecology

The ABLA/VASC, McCall Family ET represents higher elevation ABLA/VASC forests located on soils derived from granitic glacial till. At these higher elevations in upper subalpine and timberline forests, this ET is limited to cool, moist, north-facing slopes where subalpine fir is more competitive than whitebark pine and forms climax stands. The whitebark pine/grouse whortleberry habitat type occurs on adjacent south-facing slopes, while the Engelmann spruce/grouse whortleberry habitat type inhabits adjacent sites with high soil moisture. Whitebark and lodgepole pine are seral to the more shade tolerant subalpine fir and Engelmann spruce on these cooler, more moist sites.

Succession

Sample sites in the ALBA/VASC, McCall Family ET with no overstory subalpine fir and small-size class lodgepole and whitebark pine fall within successional stage (D) described below. Sample sites with overstory subalpine fir and Engelmann spruce and larger, less dense lodgepole and whitebark pine fall within the successional stage (E) or (F) described below.

A likely successional pathway for the ALBA/VASC, McCall Family ET begins with a brief herbaceous stage (A) in which Ross' sedge and heartleaf arnica regenerate rapidly from underground rhizomes and seeds, respectively, and quickly dominate the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand, with subalpine fir and Engelmann spruce seedlings in the understory (C), and then by a mature lodgepole pine and whitebark pine stand, with understory subalpine fir and Engelmann spruce (D). Low to moderate severity fires at stages (C) and (D) will maintain the stand at each respective stage, while severe fire will completely reset the successional pathway. With a continued lack of fire, a mixed subalpine fir, Engelmann spruce, lodgepole, and whitebark pine stand develops (E). A low intensity fire at stage (E) will maintain the mixed stand, while a moderate severity fire will return the stand to stage (D). Lodgepole pine will eventually drop out of the overstory and be replaced by subalpine fir resulting in a climax stand of mixed subalpine fir and whitebark pine with strong subalpine fir regeneration and scattered adult Engelmann spruce (F). Regeneration of whitebark pine and Engelmann spruce at stage (F) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for subalpine fir, which is more shade tolerant than both whitebark pine and Engelmann spruce. Severe fires at stages (E) and (F) will completely reset the successional pathway.

Management considerations

This ET occurs almost exclusively within wilderness boundaries, and traditional management issues important in montane and subalpine forests, including timber harvest and prescribed fire, are of little importance. Natural forest fires occur at broad intervals, on the order of three to fouer centuries between burns. This ET provides important habitat for black and grizzly bears, which feed on whitebark pine cones and the berries of grouse whortleberry.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/grouse whortleberry, Swapps Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Swapps Family ET features relatively clay-rich soils compared to the McCall Family ET.

Table 18—Summary of environmental variables for the ABLA/VASC, McCall Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,986	2,795	3,137
Slope (%)	36	11	62
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	723	662	788
Degree days	11,890	10,100	13,620
Frost-free days	17.5	16.5	18.4
Site water balance (mm/year)	-151	-184	-95
Average annual temperature (°C)	0	-1	1
Total annual potential evapotranspiration (mm)	443	393	495
Summer radiation (KJ)	19,180	17,490	20,450
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	66	35	94
Clay (% in particle size control section)	11	6	14
pH (in particle size control section)	4.8	4.6	5
Available water capacity (mm/m)	59	14	112
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	5
Exposed bedrock	0	0	0
Gravel	1	0	3
Cobble	3	1	7
Stones	7	3	10
Boulders	6	3	10
Litter	36	15	55
Wood	7	3	10
Moss and lichen	9	1	30
Basal vegetation	31	15	45
Water	0	0	0

Table 19—Constancy/cover table for common plant species occurring in the ABLA/VASC, McCall Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	Whitebark pine	57	14	10	20
PIEN	*Picea engelmannii*	Engelmann spruce	100	14	5	20
Subdominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	2	1	5
PIAL	*Pinus albicaulis*	Whitebark pine	57	9	1	15
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	43	2	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	71	6	1	10
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	5	1	15
PIAL	*Pinus albicaulis*	Whitebark pine	86	2	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	86	2	1	3
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	11	5	25
PIAL	*Pinus albicaulis*	Whitebark pine	100	3	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	100	2	1	3
Shrubs:						
VASC	*Vaccinium scoparium*	Grouse whortleberry	100	37	15	75
Forbs:						
AQCO	*Aquilegia coerulea*	Colorado blue columbine	43	1	1	1
ARCO9	*Arnica cordifolia*	Heartleaf arnica	100	4	1	15
CHAN9	*Chamerion angustifolium*	Fireweed	43	1	1	1
PYMI	*Pyrola minor*	Lesser wintergreen	43	2	1	3
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	57	2	1	3
Graminiods:						
CARO5	*Carex rossii*	Ross' sedge	86	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 20—Stand characteristics for the ABLA/VASC, McCall Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---*m^2/ha*---		-------*Centimeters*-------			
ABLA	5.1	2.3–13.8	26.0	13.0–36.1	138	32–222
PIAL	19.5	9.2–27.6	31.5	13.7–58.4	405	54–879
PICOL	21.4	2.3–52.8	27.2	14.0–45.2	474	44–1,299
PIEN	15.2	4.6–36.7	41.7	13.5–74.4	178	20–398

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	27.9	25	168
PIAL	33.8	13	219
PICOL	29.7	—	160
PIEN	36.6	19	203

Subalpine Fir/Grouse Whortleberry, Elting Family Ecological Type

Abies lasiocarpa/Vaccinium scoparium, Elting Family Ecological Type

ABLA/VASC, Elting Family ET

N = 6

Distribution

The subalpine fir/grouse whortleberry, Elting Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs around Blue Ridge and the headwaters of Sawmill and Canyon Creeks, to the south and east of Louis Lake in a network of diabasic gabbro dikes that have intruded into the Louis Lake Pluton, near Sweetwater Gap at the headwaters of the Middle Fork of the Popo Agie River, and near Dickinson Park. This ET may also occur in the North Fork Popo Agie drainage and in the northern study area; however, no sample sites occurred in these areas. It is a component of map units 309L, 309A, and 310L.

Environment

Aspect: East [1], east-northeast [1], north [1], northeast [1], north-northeast [1], northwest [1].

Landforms and Landscape Position: Lower backslopes and footslopes.

Parent Materials: Colluvium over residuum.

When this type occurs around Blue Ridge and the headwaters of Sawmill and Canyon Creeks, to the south and east of Louis Lake, and near Sweetwater Gap, parent materials are granodiorite of the Louis Lake Pluton. When this type occurs near Dickinson Park, parent material is quartz monzonite.

Bedrock: Granodiorite or quartz monzonite

When this type occurs around Blue Ridge and the headwaters of Sawmill and Canyon Creeks, to the south and east of Louis Lake, and near Sweetwater Gap, bedrock is granodiorite of the Louis Lake Pluton.When this type occurs near Dickinson Park, bedrock is quartz monzonite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 66 to 77 cm.

Additional environment data summaries are provided in Table 21.

Potential natural vegetation

The potential natural vegetation of this ecological type is the subalpine fir/grouse whortleberry habitat type whitebark pine phase (Steele and others 1983). Subalpine fir is the projected climax dominant tree species at these lower backslope and footslope positions. Although subalpine fir is the projected dominant tree species, it is rarely dominant in the overstory. Lodgepole pine is the major seral species and is commonly the most prolific overstory tree. Engelmann spruce is present at upper elevation sites. Whitebark pine is always present in the tree canopy. At upper backslope and shoulder positions upslope from the subalpine fir/grouse whortleberry, Elting Family ET, whitebark pine is the projected climax dominant tree species, and potential natural vegetation is the whitebark pine/grouse whortleberry habitat type. Subalpine fir and whitebark pine are always present and vigorously regenerating in the understory canopy layers.

Grouse whortleberry forms a dense low shrub layer. Other shrub species are either lacking or occur at low abundance. Prickly currant may occur in moist microsites. The herbaceous layer of this ET is typically sparse with the exception of heartleaf arnica, which may occur at greater abundance. Other forbs that may occur scattered across the understory include Colorado blue columbine, fireweed, sidebells wintergreen, and manyray goldenrod. Silvery lupine may occur in the herbaceous layer at the lower elevation range of this ecological type. Ross' sedge, spike trisetum, and Wheeler's bluegrass are the most common graminoids. Northern reedgrass may occur in moist microsites. Summaries of species constancy/cover and stand characteristics are provided in Tables 22 and 23, respectively.

Soils

Soils in the ABLA/VASC, Elting Family ET were mostly deep and sandy, with a low to moderate degree of soil development, moderate to high coarse fragment content (40–81%, avg. 63%), and low to moderate amounts of clay (5–20%, avg. 12%). A litter layer typically occurs at the soil surface (avg. 4 cm thick). A typical soil features an A/Bw/C-Cr horizonation. An E-horizon (avg. 20 cm) sometimes occurs directly below the A-horizon. Diagnostic soil

horizons include an ochric epipedon (avg. 14 cm thick) and a cambic horizon (avg. 32 cm thick). Particle size class was loamy-skeletal [3] and sandy-skeletal [3]. The soils were classified as Typic Dystrocryepts and Typic Eutrocryepts.

Typical pedon description

Soil Classification: Sandy-skeletal, mixed, Typic Dystrocryepts

Oi—0 to 2 cm: slightly decomposed plant material; abrupt wavy boundary.

A—2 to 8 cm: black (10YR 2/1) fine gravelly sandy loam, dark grayish brown (10YR 4/2), dry; 61% sand; 11% clay; moderate fine granular structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine irregular pores; 7% 76- to 250-mm unspecified fragments and 17% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.1, Bromcresol green; abrupt wavy boundary.

Bw1—8 to 29 cm: brown (7.5YR 4/3) very gravelly coarse sandy loam, light yellowish brown (10YR 6/4), dry; 69% sand; 12% clay; moderate medium granular structure, and moderate medium subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very coarse roots and common very fine roots; common fine and common medium irregular and common very coarse irregular and common very fine pores; 7% 76- to 250-mm unspecified fragments and 41% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8, Bromcresol green; clear smooth boundary.

Bw2—29 to 79 cm: strong brown (7.5YR 4/6) extremely gravelly loamy coarse sand, very pale brown (10YR 7/4), dry; 86% sand; 7% clay; moderate fine granular structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium irregular and common very fine pores; 6% 76- to 250-mm unspecified fragments and 15% 601- to 3,000-mm unspecified fragments and 16% 251- to 600-mm unspecified fragments and 43% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8, Bromcresol green; clear smooth boundary.

2C—79 to 102 cm: yellowish brown (10YR 5/6) extremely gravelly coarse sand, brownish yellow (10YR 6/6), dry; 94% sand; 3% clay; single grain; loose, nonsticky, nonplastic; few fine roots and common medium roots and few very fine roots; few fine and common medium interstitial and few very fine pores; 5% 76- to 250-mm unspecified fragments and 8% 251- to 600-mm unspecified fragments and 72% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.6, Bromcresol green.

Ecology

The ABLA/VASC, Elting Family ET represents middle to lower elevation ABLA/VASC-PIAL forests located on soils derived from granitic colluvium and residuum. This ET was always found on cooler, more moist north- or east-facing slopes. At the lowest elevations (approximately <2700 m), the distribution of this ET is probably influenced by cold air drainage as it was always located on lower backslopes and footslopes near valley bottoms.

Succession

Sample sites in the ALBA/VASC, Elting Family ET with no overstory subalpine fir or Engelmann spruce, and small-size class lodgepole and whitebark pine fall within successional stages (C) or (D) described below. Sample sites with overstory subalpine fir and Engelmann spruce and larger, less dense lodgepole and whitebark pine fall within the successional stage (E) or (F) described below.

A likely successional pathway for the ALBA/VASC, Elting Family ET begins with a brief herbaceous stage (A) in which Ross' sedge and heartleaf arnica regenerate rapidly from underground rhizomes and seeds, respectively, and quickly dominate the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand, with subalpine fir and Engelmann spruce seedlings in the understory (C), and then by a mature lodgepole pine and whitebark pine stand, with understory subalpine fir and Engelmann spruce (D). Low to moderate severity fires at stages (C) and (D) will maintain the stand at each respective stage, while severe fire will completely reset the successional pathway. With a continued lack of fire, a mixed subalpine fir, Engelmann spruce, and lodgepole and whitebark pine stand develops (E). A low intensity fire at stage (E) will maintain the mixed stand, while a moderate severity fire will return the stand to stage (D). Lodgepole pine will eventually drop out of the overstory and be replaced by subalpine, fir resulting in a climax stand of mixed subalpine fir and whitebark pine with strong subalpine fir regeneration and scattered adult Engelmann spruce (F). Regeneration of whitebark pine and Engelmann spruce at stage (F) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for subalpine fir, which is more shade tolerant than both whitebark pine and Engelmann spruce. Severe fires at stages (E) and (F) will completely reset the successional pathway.

Management considerations

The ABLA/VASC, Elting Family ET is best suited for timber harvest during successional stages (C) and (D). Small clear-cuts or seed tree treatments followed by low to moderate severity broadcast burns will prepare the site for lodgepole and whitebark pine regeneration, remove disease and insects remaining in slash material, and stimulate vigorous grouse whortleberry regeneration. Timber harvest is not recommended beyond stage (D), at which point productivity begins to decrease and the stand begins to open up due to lodgepole pine mortality. Risk of catastrophic wildfire increases with stand age, and low to moderate severity fires become less common. Low to moderate severity prescribed fire can be utilized at successional stages (C), (D), and (E) to thin subalpine fir and Engelmann spruce seedlings, reduce fuel loadings, and encourage vigorous regeneration of grouse whortleberry. In climax stands, mechanical thinning of understory subalpine fir and Engelmann spruce and diseased and dying lodgepole pine is an effective means of reducing fuels without the chance of a controlled burn escalating into a severe stand replacing burn. Later stages of this ET are important habitat for black and grizzly bears, which feed on whitebark pine cones and the berries of grouse whortleberry.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/grouse whortleberry Marosa Family ET

Floristic differences: The two types are very similar floristically. However, the Marosa Family ET includes the subalpine fir/common juniper, and subalpine fir/heartleaf arnica habitat types at lower elevations, whereas the Elting Family ET includes only the subalpine fir/grouse whortleberry habitat type.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at higher elevations (avg. 2,896 m) exclusively on granitic substrates and is characterized by sandy, clay-poor soils, whereas the Marosa Family ET occurs at lower elevations (avg. 2,792 m) on both sandstone and granitic substrates and is characterized by relatively clay-rich soils.

Table 21—Summary of environmental variables for the ABLA/VASC, Elting Family ET.

General environment	**Average**	**Min**	**Max**
Elevation (m)	2,896	2,595	3,060
Slope (%)	28	13	40
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	710	663	767
Degree days	13,040	11,520	14,830
Frost-free days	18.0	17.3	19.0
Site water balance (mm/year)	-191	-266	-139
Average annual temperature (°C)	0.3	-0.3	1.1
Total annual potential evapotranspiration (mm)	468	426	537
Summer radiation (KJ)	19,070	18,300	19,930
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	63	40	81
Clay (% in particle size control section)	12	5	20
pH (in particle size control section)	5.1	4.8	5.4
Available water capacity (mm/m)	49	27	68
Ground surface components, cover	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	0	1	3
Exposed bedrock	11	0	40
Gravel	0	0	0
Cobble	4	1	7
Stones	6	1	10
Boulders	9	1	15
Litter	37	20	50
Wood	7	5	10
Moss and lichen	2	1	5
Basal vegetation	22	15	30
Water	0	0	0

Table 22—Constancy/cover table for common plant species occurring in the ABLA/VASC, Elting Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Dominant Overstory Trees:						
PIAL	*Pinus albicaulis*	Whitebark pine	67	10	3	20
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	83	11	3	15
PIEN	*Picea engelmannii*	Engelmann spruce	50	10	5	15
Subominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	50	4	3	5
PIAL	*Pinus albicaulis*	Whitebark pine	83	5	1	10
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	50	7	5	10
PIEN	*Picea engelmannii*	Engelmann spruce	67	8	1	25
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	83	5	1	10
PIAL	*Pinus albicaulis*	Whitebark pine	83	2	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	50	2	1	5
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	5	1	15
PIAL	*Pinus albicaulis*	Whitebark pine	100	2	1	5
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	50	2	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	67	2	1	3
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	Common juniper	50	3	1	5
VASC	*Vaccinium scoparium*	Grouse whortleberry	100	23	3	45
Forbs:						
ARCO9	*Arnica cordifolia*	Heartleaf arnica	83	3	1	10
CHAN9	*Chamerion angustifolium*	Fireweed	50	1	1	1
ORSE	*Orthilia secunda*	Sidebells wintergreen	67	2	1	3
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	50	1	1	1
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	67	2	1	3
TRSP2	*Trisetum spicatum*	Spike trisetum	67	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	83	2	1	3

Note: Con = A percentage of plots in which a species occurred; Cov = Average canopy cover in plots in which the species occurred.

Table 23—Stand characteristics for the ABLA/VASC, Elting Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------Centimeters-------			
ABLA	3.9	2.3–6.9	16.5	13.7–21.3	190	121–309
PIAL	1.7	6.9–39.0	25.4	7.1–54.9	603	106–1171
PICOL	1.7	2.3–30.0	24.1	9.9–48.5	551	27–1628
PIEN	6.9	4.6–9.2	34.3	13.5–53.1	173	64–284

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	17.0	17	114
PIAL	25.4	12	164
PICOL	28.7	18	194
PIEN	35.6	23	160

Subalpine Fir/Grouse Whortleberry, Marosa Family Ecological Type

Subalpine fir/Vaccinium scoparium, Marosa Family Ecological Type

ABLA/VASC, Marosa Family ET

N = 8

Distribution

The subalpine fir/grouse whortleberry, Marosa Family Ecological Type occurs across the study area within the dry mid-elevation sedimentary mountains ecoregion and in the granitic subalpine zone ecoregion of Chapman and others (2004). In the mid-elevation sedimentary mountains ecoregion, this ET occurs on northeast-facing Flathead and Tensleep sandstone. In the granitic subalpine zone ecoregion, this ET occurs in the southern study area just south of Louis Lake. It is a component of map units 43LF and 310A.

Environment

Aspect: East [1], east-northeast [3], north [1], northeast [2], west [1].

Landforms and Landscape Position: Shoulders, backslopes, and footslopes.

Parent Materials: Colluvium over residuum.

When this type occurs at lower backslope and footslope positions on the Flathead Formation, parent materials are Flathead Sandstone colluvium over sandy-shale residuum. When this type occurs at backslope and shoulder positions on the Flathead and Tensleep Formations, parent materials are Flathead or Tensleep Sandstone colluvium over residuum. When this type occurs south of Louis Lake, parent materials are granodiorite of the Louis Lake Pluton.

Bedrock: Flathead Sandstone, Tensleep Sandstone, or Granodiorite.

When this type occurs at lower backslope and footslope positions on the Flathead Formation, bedrock is sandy-shale residuum. When this type occurs at backslope and shoulder positions on the Flathead and Tensleep Formations, bedrock is Flathead or Tensleep Sandstone, respectively. When this type occurs south of Louis Lake, bedrock is granodiorite of the Louis Lake Pluton.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 70 cm.

Additional environment data summaries are provided in Table 24.

Potential natural vegetation

The potential natural vegetation of this ecological type at higher elevations (approximately >2,750 m) on backslopes and shoulders is the subalpine fir/grouse whortleberry habitat type whitebark pine phase (Steele and others 1983). At lower elevations (approximately ≤2,750 m) on backslopes and footslopes, the potential natural vegetation is the subalpine fir/grouse whortleberry habitat type grouse whortleberry phase, the subalpine fir/common juniper habitat type, or the subalpine fir/heartleaf arnica habitat type.

Subalpine fir is present in all canopy layers, and vigorous subalpine fir seedlings are present in the understory. In early seral stands, subalpine fir may only be present in the understory. Lodgepole pine is the major seral species and commonly occurs in the overstory. Engelmann spruce and whitebark pine are common at upper elevation sites. Limber pine may occur at lower elevation sites.

In the subalpine fir/grouse whortleberry habitat type whitebark pine phase and subalpine fir/grouse whortleberry habitat type grouse whortleberry phase, grouse whortleberry forms a dense low shrub layer. Other shrub species may include common juniper, russet buffaloberry, or Oregon grape. The herbaceous layer is typically sparse with the exception of heartleaf arnica and Wheeler's bluegrass, which may occur at greater abundance. Other forbs that may occur scattered across the understory include Ross' sedge, slender hawkweed, sidebells wintergreen, and fireweed.

In the subalpine fir/common juniper habitat type, common juniper, Oregon grape, kinnikinnick, and russet buffaloberry may form a low shrub layer. The herbaceous layer is characteristically sparse and may include heartleaf arnica, manyray goldenrod, alpine leafybract aster, fireweed, and Ross' sedge.

In the subalpine fir/heartleaf arnica habitat type, russet buffaloberry is the most common shrub species. Common juniper and Oregon grape may also occur at low abundance. Heartleaf arnica is always present and may be joined by manyray goldenrod, slender hawkweed, fireweed, sidebells and lesser wintergreen, bluntseed sweetroot, Wheeler's bluegrass, and Ross' sedge. Summaries of species constancy/cover and stand characteristics are provided in Tables 25 and 26, respectively.

Soils

Soils in the ABLA/VASC, Marosa Family ET were sandy and mostly deep with a moderate to high degree of soil development, moderate to high coarse fragments (35–88%, avg. 57%), and low to moderately high illuvial clay (10–25%, avg. 17%). A thin (avg. 2 cm thick) litter layer occurs at the surface. A typical soil features an A/E/Bt-Bw/C horizonation. Distinguishing soil horizons include an ochric epipedon (avg. 17 cm thick), an argillic horizon (avg. 27 cm thick), and a cambic horizon (avg. 35 cm thick). One soil featured a 27-cm thick mollic epipedon overlying a thick E-horizon (34 cm thick). This same plot had quaking aspen in the overstory. Quaking aspen leaves, which have high concentrations of cations and decompose quickly due to a low carbon to nitrogen ratio, contribute strongly to the development of thick, dark, carbon-rich surface horizons (Cryer and Murray 1992; Howard 1996; Legare and others 2005). Particle size class was loamy-skeletal. The soils were classified as Inceptic Haplocryalfs [4], Mollic Haplocryalfs [1], Typic Eutrocryepts [1], Typic Dystrocryepts [1], and Typic Cryorthents [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Inceptic Haplocryalfs

Oi—0 to 1 cm: slightly decomposed plant material; abrupt wavy boundary.

Oe—1 to 2 cm: moderately decomposed plant material; abrupt wavy boundary.

A—2 to 15 cm: dark grayish brown (10YR 4/2) fine gravelly fine sandy loam, brown (10YR 5/3), dry; 63% sand; 16% clay; weak medium subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many medium roots and many coarse roots and common very coarse roots and common very fine roots; common fine and many medium and many coarse and common very coarse and common very fine pores; 4% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 10% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 13% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; clear wavy boundary.

E—15 to 46 cm: brown (10YR 4/3) very stony fine sandy loam, light gray (10YR 7/2), dry; 77% sand; 15% clay; weak fine subangular blocky structure, and moderate fine granular structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many coarse roots and common very coarse roots and common very fine roots; common fine and common medium and many coarse and common very coarse and common very fine pores; 7% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 18% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 24% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0; clear wavy boundary.

Bt—46 to 69 cm: brown (7.5YR 4/4) very stony fine sandy loam, light brown (7.5YR 6/4), dry; 74% sand; 18% clay; weak coarse subangular blocky structure, and moderate medium subangular blocky structure, and moderate very fine subangular blocky structure; friable, moderately hard, slightly sticky, slightly plastic; common medium roots and common very fine roots; common fine and common medium and common very fine pores; 2% patchy faint clay films on all faces of peds; 9% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 13% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 26% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear wavy boundary.

Bw—69 to 91 cm: brown (7.5YR 4/3) very stony fine sandy loam, light brown (7.5YR 6/3), dry; 82% sand; 16% clay; weak fine subangular blocky structure, and weak very fine subangular blocky structure; very friable, slightly hard, slightly sticky, slightly plastic; common very fine and fine roots and common medium roots; common fine and common medium and common very fine pores; 8% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 10% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 39% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear wavy boundary.

C—91 to 104 cm: strong brown (7.5YR 4/6) very stony fine sandy loam, strong brown (7.5YR 5/6), dry; 83% sand; 17% clay; weak fine subangular blocky structure; friable, moderately hard, slightly sticky, slightly plastic; common fine and common medium and common very fine pores; 4% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 6% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 45% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7.

Ecology

On the Flathead or Tensleep Formation, the ABLA/VASC, Marosa Family ET represents subalpine fir forests located on clay-rich soils derived from sandstone or sandy-shale. Along the eastern flank of the WRR, soils derived from Flathead or Tensleep Sandstone tend to support lodgepole pine forests that may reach a stable state akin to what some might consider climax vegetation. However, along cold-air drainages and in pockets of finer-textured soil, lodgepole pine on the Flathead and Tensleep Formations may give way to mature subalpine fir forests given sufficient time between burns, on the order of 300 to 400 years.

South of Louis Lake, the ABLA/VASC, Marosa Family ET represents ABLA/VASC-VASC and middle to lower elevation ABLA/VASC-PIAL forests located on clay-rich soils derived from granitic colluvium and residuum. In general, this ET was always found on cooler, mesic north- or east-facing slopes. This ET may be located on south- or west-facing slopes at higher elevations where the clay-rich soils retain moisture long into the summer months, allowing subalpine fir to extend its distribution onto these warmer, drier sites.

Succession

Sample sites in the ABLA/VASC-VASC and ABLA/VASC-PIAL habitat types share similar successional pathways, with the exception that the former features only lodgepole pine as a seral species, while the latter features lodgepole and whitebark pine as seral species. Stands with no overstory subalpine fir and small-size class lodgepole and whitebark pine fall within successional stages (C) or (D) described below. Sample sites with overstory subalpine fir and Engelmann spruce and larger, less dense lodgepole and whitebark pine fall within the successional stage (E) or (F) described below.

A likely successional pathway for the ALBA/VASC-VASC and ABLA/VASC-PIAL habitat types begins with a brief herbaceous/shrub stage (A) in which Ross' sedge, heartleaf arnica, and grouse whortleberrry regenerate rapidly from underground rhizomes or seeds (heartleaf arnica), and quickly dominate the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically serotinous on sandstone bedrock. Regeneration tends to be synchronous on sandstone, forming even-aged stands. On granitic bedrock, the cones of lodgepole pine are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open pole-sized lodgepole and whitebark pine stand, with subalpine fir seedlings in the understory (C), and then by a mature lodgepole pine and whitebark pine stand, with understory subalpine fir (D). At stages (C) and (D), Engelmann spruce seedlings may occur at higher elevation sites. Low to moderate severity fires at stages (C) and (D) will maintain the stand at each respective stage, while severe fire will completely reset the successional pathway. With a continued lack of fire, a mixed subalpine fir, lodgepole, and whitebark pine stand develops (E). A low intensity fire at stage (E) will maintain the mixed stand, while a moderate severity fire will return the stand to stage (D). Lodgepole pine will eventually drop out of the overstory and be replaced by subalpine fir resulting in a climax stand of mixed subalpine fir and whitebark pine with strong subalpine fir regeneration and scattered adult Engelmann spruce (F). Regeneration of whitebark pine at stage (F) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for subalpine fir, which is more shade tolerant than whitebark pine. Severe fires at stages (E) and (F) will completely reset the successional pathway.

Management considerations

The ABLA/VASC-VASC and ABLA/VASC-PIAL habitat types are highly productive and are best suited for timber harvest on backslope and footslope positions at successional stages (C) and (D). The highly productive nature of this ET makes it ideal for short rotation harvests of large, high quality timber. Since forested stands of this ecological type tend to be even aged, timber harvest should occur shortly after stands reach maturity and before mountain pine beetle outbreaks reach epidemic proportions. Harvest schedules should be designed to create age-class mosaics across the landscape (Bradley and others 1992). Since subalpine fir is a wind-dispersed species, managers should consider the adjacency of subalpine fir seed trees when deciding on harvest opening size. Broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe, open serotinous cones on downed branches, remove duff and prepare mineral soil for lodgepole pine regeneration, and increase forage production for big game in the years shortly after timber harvest. Forage and browse production is high during the initial stages of this ecological type. Forage production drops continually as stand age increases, and Oregon grape may be the only species with appreciable forage value in climax stands. At footslope positions on Flathead and Tensleep Sandstone, this ecological type provides important shelter and hiding cover for elk due to its adjacency to grassland and sagebrush communities on nearby Gros Ventre and Amsden slopes.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/grouse whortleberry, Elting Family ET

Floristic differences: The two types are very similar floristically. However, the Marosa Family ET includes the subalpine fir/common juniper and subalpine fir/heartleaf arnica habitat types at lower elevations, whereas the Elting Family ET includes only the subalpine fir/grouse whortleberry habitat type.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at higher elevations (avg. 2,896 m) exclusively on granitic substrates and is characterized by sandy, clay-poor soils, whereas the Marosa Family ET occurs at lower elevations (avg. 2,792 m) on both sandstone and granitic substrates and is characterized by relatively clay-rich soils.

Ecological Type 2

Type: Warm subalpine fir forests, Elting Family ET

Floristic differences: The two types are very similar floristically. However, the Marosa Family ET includes the subalpine fir/grouse whortleberry habitat type at higher elevations, whereas the Elting Family ET never includes this habitat type.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at lower elevations (avg. 2,660 m) exclusively on granitic substrates and is characterized by sandy, clay-poor soils, whereas the Marosa Family ET occurs at higher elevations (avg. 2,792 m) on both sandstone and granitic substrates and is characterized by relatively clay-rich soils.

Table 24—Summary of environmental variables for the ABLA/VASC, Marosa Family ET.

General environment	**Average**	**Min**	**Max**
Elevation (m)	2,792	2,675	2,882
Slope (%)	19	8	41
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	669	633	703
Degree days	14,700	13,560	16,020
Frost-free days	18.9	18.3	19.5
Site water balance (mm/year)	-239	-265	-202
Average annual temperature (°C)	1.1	0.6	1.7
Total annual potential evapotranspiration (mm)	550	500	604
Summer radiation (KJ)	19,850	19,290	20,530
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	57	35	88
Clay (% in particle size control section)	17	10	25
pH (in particle size control section)	5.0	4.7	5.4
Available water capacity (mm/m)	53	26	68
Ground surface components, cover	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	5
Exposed bedrock	6	0	30
Gravel	2	0	5
Cobble	7	0	20
Stones	6	0	20
Boulders	8	0	30
Litter	32	20	60
Wood	15	5	30
Moss and lichen	2	1	6
Basal vegetation	19	0	30
Water	0	0	0

Table 25—Constancy/cover table for common plant species occurring in the ABLA/VASC, Marosa Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	100	14	10	25
Subdominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	62	6	1	10
PIAL	*Pinus albicaulis*	Whitebark pine	50	5	3	10
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	62	4	3	5
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	88	6	3	15
PIAL	*Pinus albicaulis*	Whitebark pine	50	2	1	3
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	75	2	1	5
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	4	1	10
PIAL	*Pinus albicaulis*	Whitebark pine	50	1	1	1
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	100	2	1	3
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	Common juniper	62	4	1	10
SHCA	*Shepherdia canadensis*	Russet buffaloberry	50	6	1	10
VASC	*Vaccinium scoparium*	Grouse whortleberry	75	26	15	35
Forbs:						
ARCO9	*Arnica cordifolia*	Heartleaf arnica	100	5	1	10
CHAN9	*Chamerion angustifolium*	Fireweed	88	1	1	1
HITRG2	*Hieracium triste* var. *gracile*	Slender hawkweed	62	1	1	3
ORSE	*Orthilia secunda*	Sidebells wintergreen	62	1	1	3
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	88	3	1	10
TRSP2	*Trisetum spicatum*	Spike trisetum	62	1	1	3
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	88	2	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 26—Stand characteristics for the ABLA/VASC, Marosa Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
ABLA	6.7	2.3–13.8	20.6	12.7–33.8	232	45–665
PIAL	12.2	6.9–18.4	28.4	13.0–49.0	279	116–405
PICOL	20.2	4.6–41.3	24.4	13.2–54.6	538	101–1235
PIEN	3.4	2.3–4.6	40.6	27.9–49.5	32	15–49
POTR5	4.6	—	14.2	9.4–19.0	412	—

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
ABLA	23.1	19	84
PIAL	30.7	13	200
PICOL	26.4	19	151
PIEN	47.2	20	152

Warm Subalpine Fir Forests, Elting Family Ecological Type

Warm *Abies lasiocarpa* Forests, Elting Family Ecological Type

Warm ABLA Forests, Elting Family ET

N = 3

Distribution

The Warm Subalpine Fir Forests, Elting Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs on rocky mountain slopes characterized by outcrops of foliated granodiorite and talus fields, located south and east of Louis Lake, and directly west of Bayer Mountain. It is a component of map unit 310A.

Environment

Aspect: Northeast [1], northwest [1], west [1].

Landforms and Landscape Position: Shoulders and backslopes.

Parent Materials: Granodiorite colluvium over granodiorite residuum.

Bedrock: Granodiorite of the Louis Lake Pluton

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 64 cm.

Additional environment data summaries are provided in Table 27.

Potential natural vegetation

The potential natural vegetation of this ecological type includes the subalpine fir/common juniper, subalpine fir/Oregon grape, and the subalpine fir/heartleaf arnica habitat types (Steele and others 1983). Subalpine fir is the projected climax dominant tree species on these sheltered backslopes. Lodgepole pine, Engelmann spruce, and occasionally Rocky Mountain Douglas-fir are major seral species. Quaking aspen may be dominant in early seral stages, especially at extremely bouldery sites. Subalpine fir and whitebark pine are always present and vigorously regenerating in the understory canopy layers.

Common juniper and russet buffaloberry are always found in the shrub layer. Russet buffaloberry may sometimes be found at great abundance, especially in younger stands (Steele and others 1983). Oregon grape is the predominant species in the subalpine fir/Oregon grape habitat type. Other shrub species may include kinnikinnick, antelope bitterbrush, Utah snowberry, and whiskey currant.

The herbaceous layer tends to be species rich; however, no one species ever occurs at great abundance. The most common herbaceous species were lance-leaved stonecrop, umber pussy-toes, spiny milkvetch, lesser wintergreen, ballhead sandwort, many-flowered phlox, and Wheeler's bluegrass. Heartleaf arnica and Ross' sedge may be prominent members of the herbaceous layer immediately following fire. The herbaceous layer of early seral stages tends to be more graminoid rich and may include western needlegrass, Idaho and spike fescues, little ricegrass, and squirreltail. Summaries of species constancy/cover and stand characteristics are provided in Tables 28 and 29, respectively.

Soils

Soils in the Warm Subalpine Fir Forests, Elting Family ET were moderately deep and deep, sandy, and characterized by a low degree of soil development, high coarse fragments (avg. 70%), and low clay (avg. 8%). A thin (avg. 2 cm thick) litter layer may occur at the surface. A typical soil features an A/Bw/C-Cr horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 12 cm thick) and a cambic horizon (avg. 36 cm thick). Entisols featured no diagnostic subsurface horizons. Particle size class was sandy-skeletal [2] and loamy-skeletal [1]. The soils were Typic Dystrocryepts [2] and Typic Cryorthents [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Typic Dystrocryepts

Oi—0 to 1 cm: slightly decomposed plant material; abrupt smooth boundary.

A—1 to 5 cm: brown (10YR 4/3) extremely gravelly sandy loam, light brownish gray (10YR 6/2), dry; 65% sand; 11% clay; weak medium granular structure, and weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and few medium roots and common very fine roots; common fine and few medium and common very fine pores; 17% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 45% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; abrupt smooth boundary.

Bw—5 to 36 cm: dark yellowish brown (10YR 4/4) extremely gravelly sandy loam, light yellowish brown (10YR 6/4), dry; 67% sand; 18% clay; weak very fine subangular blocky structure, and weak fine subangular blocky structure; friable, soft, slightly sticky, slightly plastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 23% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 48% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear smooth boundary.

2C1—36 to 61 cm: extremely gravelly coarse sand; 94% sand; 3% clay; single grain; loose, slightly sticky, nonplastic; common fine roots and few medium roots and common very fine roots; common fine and few medium and common very fine pores; 11% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 69% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; Colors dry and moist are variegated.; clear smooth boundary.

2C2—61 to 105 cm: extremely gravelly coarse sand; 96% sand; 2% clay; single grain; loose, slightly sticky, nonplastic; common very fine and fine roots and few medium roots; common very fine and fine and few medium pores; 12% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 72% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; Colors dry and moist are variegated.

Ecology

The Warm ABLA Forests, Elting Family ET represents middle to lower elevation subalpine fir forests located on soils derived from granitic colluvium and residuum. This ET was always found on cool, dry northwest- and west-facing slopes. Average annual temperature and growing degree days were higher than in the cooler subalpine fir forests, including ABLA/VASC, Elting Family ET. The Warm ABLA Forests, Elting Family ET is located above valley bottoms on backslopes and shoulders, and the distribution of this ET is most likely not influenced by cold air drainage, but rather by the indirect effect of slope aspect in creating cooler air temperatures than on adjacent south-facing slopes. The rocky, sandy soils have very little water holding capacity and available nutrients, and are extremely unproductive.

Succession

Sample sites in the Warm ABLA Forests, Elting Family ET were at successional stages (C) and (D) and were seral to lodgepole pine. At sites where Rocky Mountain Douglas-fir is the major seral species, a herbaceous/shrub stage (A), which may include some limber pine regeneration, follows directly from a stand-replacing burn (Bradley and others 1992). In the absence of fire, the herbaceous/shrub stage is followed by a Rocky Mountain Douglas-fir, limber pine, quaking aspen seedling and sapling stand (B). A fire of any severity at stage (B) will reset the successional pathway to the herbaceous/shrub stage. A mixed Rocky Mountain Douglas-fir, limber pine, and quaking aspen pole stand with subalpine fir regeneration follows the seedling and sapling stand (C) in the absence of fire. Low severity fires maintain the pole stand, while moderate severity fires at stage (C) typically escalate into severe fires and reset the successional pathway. In the continued absence of fire, quaking aspen begins to decline as the understory becomes shaded, and the pole stand is followed by a mature limber pine and Rocky Mountain Douglas-fir stand with strong subalpine fir regeneration (D) and then by a mixed Rocky Mountain Douglas-fir, limber pine, subalpine fir stand (E). Low severity fires at stages (D) or (E) maintain each respective stage, while moderate severity fires favor the slightly more fire resistant Rocky Mountain Douglas-fir and lead to an open Rocky Mountain Douglas-fir forest with Rocky Mountain Douglas-fir regeneration (D1). Stage (D1) is maintained by low to moderate severity fires. In the absence of fire, stage (D1) progresses to stages (D) and (E). A climax stand (F) of mature subalpine fir with plentiful subalpine fir regeneration follows from stage (E) and is maintained by low severity burns or the absence of fire. Severe fires at stages (D), (D1), (E), and (F) completely reset the successional pathway.

At sites where lodgepole pine is the major seral species, a herbaceous/shrub stage (A), which may include quaking aspen sprouts, follows directly from a stand-replacing burn (Bradley and others 1992). Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven aged lodgepole pine, whitebark pine, quaking aspen seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole pine, whitebark pine, and quaking aspen stand, with subalpine fir and Engelmann spruce seedlings in the understory (C), and then by a mature lodgepole pine and whitebark pine stand, with understory subalpine fir and Engelmann spruce (D). Low to moderate severity fires at stages (C) and (D) will maintain the stand at each respective stage, while severe fire will completely reset the successional pathway. With a continued lack of fire, quaking aspen begins to decline, and a mixed subalpine fir, whitebark pine, Engelmann spruce, and lodgepole pine stand develops (E). A low intensity fire at stage (E) will maintain the mixed stand, while a moderate severity fire will return the stand to stage (D). Lodgepole pine will eventually drop out of the overstory and be replaced by subalpine fir, resulting in a climax stand of mixed subalpine fir with strong subalpine fir regeneration and scattered adult whitebark pine and Engelmann spruce (F). Regeneration of Engelmann spruce at stage (F) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings. Regeneration success tends to be greater for subalpine fir, which is more shade tolerant than Engelmann spruce. Severe fires at stages (E) and (F) will completely reset the successional pathway.

Management considerations

The Warm Subalpine Fir Forests, Elting Family ET is not suited for timber harvest due to low productivity and the inherent difficulty of accessing these rocky sites with logging equipment. However, small clear-cuts (2–4 ha) or seed tree treatments followed by low to moderate severity broadcast burns will reinvigorate older stands, reduce fuels, control disease and insects, and stimulate vigorous quaking aspen and lodgepole pine regeneration. Risk of catastrophic wildfire increases with stand age, and low to moderate severity fires become less common. Low to moderate severity prescribed fire can be utilized at successional stages (C), (D), and (E) to thin subalpine fir and Engelmann spruce seedlings and reduce fuel loadings. In climax stands, mechanical thinning of understory subalpine fir and Engelmann spruce and diseased and dying lodgepole pine is an effective means of reducing fuels without the chance of a controlled burn escalating into a severe, stand replacing burn.

Mountain pine beetle epidemics often begin in warmer, lower elevation subalpine forests, and move from there into upper elevation forests (Eggers 1990). Managers concerned with mountain pine beetle epidemics in upper elevation subalpine forests may want to consider monitoring the Warm ABLA Forests, Elting Family ET for signs of beetle activity, especially at early seral stages when lodgepole pine is dominant. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques for controlling mountain pine beetle in stands dominated by lodgepole pine.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/grouse whortleberry Marosa Family ET

Floristic differences: The two types are very similar floristically. However, the Marosa Family ET includes the subalpine fir/grouse whortleberry habitat type at higher elevations, whereas the Elting Family ET never includes this habitat type.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at lower elevations (avg. 2660 m) exclusively on granitic substrates and is characterized by sandy, clay-poor soils, whereas the Marosa Family ET occurs at higher elevations (avg. 2792 m) on both sandstone and granitic substrates and is characterized by relatively clay-rich soils.

Ecological Type 2

Type: Subalpine fir/grouse whortleberry Elting Family ET

Floristic differences: The two types are very similar floristically. However, the ABLA/VASC, Elting Family ET is characterized by the subalpine fir/grouse whortleberry habitat type, whereas the Warm ABLA Forests, Elting Family ET includes a number of subalpine fir habitat types that occur at the warm, dry end of the subalpine fir series.

Environmental differences: The two types differ environmentally in that the ABLA/VASC, Elting Family ET occurs at cooler, higher elevations (avg. 2896 m), whereas the Warm ABLA Forests, Elting Family ET occurs at warmer, lower elevations (avg. 2660 m).

Table 27—Summary of environmental variables for the Warm ABLA, Elting Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,660	2,647	2,681
Slope (%)	30	22	39
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	633	629	637
Degree days	15,750	15,660	15,940
Frost-free days	19.4	19.3	19.5
Site water balance (mm/year)	-266	-273	-263
Average annual temperature (°C)	1.5	1.4	1.6
Total annual potential evapotranspiration (mm)	528	519	534
Summer radiation (KJ)	18,840	18,610	19,250
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	70	43	87
Clay (% in particle size control section)	8	5	15
pH (in particle size control section)	4.8	4.7	4.9
Available water capacity (mm/m)	20	9	33
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	5	1	10
Exposed bedrock	5	1	10
Gravel	11	3	15
Cobble	8	3	15
Stones	4	3	5
Boulders	5	3	10
Litter	15	10	20
Wood	10	5	15
Moss and lichen	9	2	20
Basal vegetation	27	10	35
Water	0	0	0

Table 28—Constancy/cover table for common plant species occurring in the Warm ABLA, Elting Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	67	8	1	15
Subdominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	4	1	7
PIAL	*Pinus albicaulis*	Whitebark pine	67	8	5	10
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	100	5	1	10
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	5	1	10
PIAL	*Pinus albicaulis*	Whitebark pine	100	9	5	15
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	100	2	1	3
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	8	5	10
PIAL	*Pinus albicaulis*	Whitebark pine	100	6	5	7
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	100	1	1	1
PIEN	*Picea engelmannii*	Engelmann spruce	67	1	1	1
POTR5	*Populus tremuloides*	Quaking aspen	67	4	1	7
Shrubs:						
ARUV	*Arctostaphylos uva-ursi*	Kinnikinnick	67	4	3	5
JUCOD	*Juniperus communis* var. *depressa*	Common juniper	100	4	3	5
MARE11	*Mahonia repens*	Oregon grape	67	2	1	3
PUTR2	*Purshia tridentata*	Antelope bitterbrush	67	1	1	1
SHCA	*Shepherdia canadensis*	Russet buffaloberry	100	4	1	10
Forbs:						
ANUM	*Antennaria umbrinella*	Umber pussy-toes	67	5	3	7
ASKE	*Astragalus kentrophyta*	Spiny milkvetch	67	2	1	3
ERCO24	*Eremogone congesta*	Ballhead sandwort	67	1	1	1
PHMU3	*Phlox multiflora*	Many-flowered phlox	67	1	1	1
PYMI	*Pyrola minor*	Lesser wintergreen	67	1	1	1
SELA	*Sedum lanceolatum*	Lance-leaved stonecrop	100	1	1	1
Grasses:						
ELEL5	*Elymus elymoides*	Squirreltail	67	1	1	1
PIEX3	*Piptatherum exiguum*	Little ricegrass	67	2	1	3
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	5	3	10
TRSP2	*Trisetum spicatum*	Spike trisetum	67	4	3	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 29—Stand characteristics for the Warm ABLA, Elting Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------*Centimeters*-------			
ABLA	2.3	2.3–2.3	17.5	16.5–18.3	96	86–106
PIAL	8.0	2.3–13.8	20.6	15.0–22.9	257	72–442
PICOL	4.6	2.3–92	26.7	15.5–32.3	104	32–153

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	17.5	9	80
PIAL	21.3	12	130
PICOL	24.9	17	156

Subalpine Fir/Oregon Grape, Frisco Family Ecological Type

Abies lasiocarpa/Mahonia repens, Frisco Family Ecological Type

ABLA/MARE11, Frisco Family ET

N = 4

Distribution

The subalpine fir/Oregon grape, Frisco Family Ecological Type occurs along the eastern flank of the WRR within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from Sinks Canyon southeast to Limestone Mountain. It is a component of map unit 43L.

Environment

Aspect: North [1], north-northwest [1], northwest [2].

Landforms and Landscape Position: Backslopes.

Parent Materials: Mixed limestone and dolomite colluvium.

Bedrock: Cambrian Gros Ventre Shale, Cambrian or Mississipian Limestone, Ordovician Dolomite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 67 cm.

Additional environment data summaries are provided in Table 30.

Potential natural vegetation

The potential natural vegetation for this ecological type is the subalpine fir/Oregon grape habitat type-Oregon grape phase (Steele and others 1983). Subalpine fir rarely dominates in the overstory canopy layers. Rocky Mountain Douglas-fir and limber pine are major seral species on limestone and dolomite slopes. Subalpine fir is always well represented in the small size classes and exhibits vigorous regeneration in the understory.

Oregon grape is always present, sometimes at relatively low abundance. Steele and others (1983) also consider Oregon boxleaf an indicator of this habitat type; however, Oregon boxleaf was not found in the shrub layer of any of the sample sites. Russet buffaloberry and common juniper are other common shrubs found in this ecological type. Common juniper was abundant (20%) at one early seral site dominated by Rocky Mountain Douglas-fir and limber pine. Given enough time, common juniper should decline in abundance as subalpine fir achieves dominance and shades the understory. Snowbrush ceanothus is indicative of recent forest fire activity.

The herbaceous layer is surprisingly species rich relative to other subalpine fir habitat types found along the eastern slope of the WRR. Heartleaf arnica, harebell, elkweed, northern bedstraw, bluntseed sweetroot, manyray goldenrod, and alpine leafybract aster are the most common forbs. Spike fescue and Wheeler's bluegrass are the most common graminoids. Summaries of species constancy/cover and stand characteristics are provided in Tables 31 and 32, respectively.

Soils

Soils in the ABLA/MARE11, Frisco Family ET are deep and carbonate rich, with a moderate to high degree of soil development, moderately high coarse fragments (avg. 54%), and moderately high clay (avg. 20%). A thin (avg. 3 cm thick) litter layer occurs at the surface. A typical soil features an A/Bt-Bw/Bk horizonation. Distinguishing soil horizons include an ochric epipedon (avg. 7 cm thick), an argillic horizon (avg. 38 cm thick), and a thick calcic horizon (avg. 50 cm thick). Inceptisols featured a cambic horizon (avg. 62 cm thick) in place of an argillic horizon. One soil featured a 32-cm thick Mollic epipedon. Particle size class was loamy-skeletal. Soils were Eutric Haplocryalfs, Calcic Argicryolls, and Typic Eutrocryepts.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Eutric Haplocryalfs

Oi—0 to 2 cm: slightly decomposed plant material; abrupt wavy boundary.

Oe—2 to 4 cm: moderately decomposed plant material; abrupt smooth boundary.

BAt—4 to 14 cm: dark brown (10YR 3/3) medium gravelly sandy clay loam, brown (10YR 5/3), dry; 54% sand; 23% clay; weak very thin platy structure, and moderate very fine subangular blocky structure, and moderate medium subangular blocky structure; friable, moderately hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots; many fine and common medium and many very fine pores; 14% patchy faint clay films on all faces of peds; 4% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 14% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; slightly alkaline, pH 7.5; Colors: Dry color is multiple colors and organic stains; clear wavy boundary.

Bt—14 to 30 cm: dark yellowish brown (10YR 4/4) extremely gravelly sandy clay loam, yellowish brown (10YR 5/4), dry; 58% sand; 22% clay; moderate very fine subangular blocky structure, and weak fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots; many very fine and fine and common medium and common coarse pores; 2% patchy faint clay films on surfaces along root channels and 2% patchy faint clay films on all faces of peds; 4% fine distinct carbonate nodules in matrix; 9% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 16% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 37% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; slightly alkaline, pH 7.7; gradual irregular boundary.

Btk—30 to 52 cm: brown (10YR 4/3) extremely gravelly sandy clay loam, light yellowish brown (10YR 6/4), dry; 66% sand; 21% clay; weak very fine subangular blocky structure, and weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots; common very fine and fine and common medium and common coarse pores; patchy distinct carbonate coats on bottom surfaces of rock fragments and 4% patchy faint clay films on top surfaces of rock fragments; 8% fine distinct carbonate nodules in matrix; 14% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 33% nonflat subrounded indurated 2- to 75-mm unspecified fragments; strong effervescence; slightly alkaline, pH 7.6; clear wavy boundary.

Bk—52 to 80 cm: brown (10YR 5/3) very gravelly sandy loam, pale brown (10YR 6/3), dry; 79% sand; 19% clay; weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common very fine and fine roots and common medium roots and common coarse roots; common very fine and fine and common medium and common coarse pores; patchy distinct carbonate coats on rock fragments; 15% fine faint carbonate masses in matrix; 18% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 38% nonflat subrounded indurated 2- to 75-mm unspecified fragments; strong effervescence; slightly alkaline, pH 7.8; clear wavy boundary.

BCk—80 to 102 cm: yellowish brown (10YR 5/4) very gravelly sandy loam, light yellowish brown (10YR 6/4), dry; 77% sand; 17% clay; massive; very friable, soft, slightly sticky, nonplastic; few fine roots and few medium roots and common very fine roots; common very fine and fine and common medium pores; patchy distinct carbonate coats on rock fragments; 18% fine faint carbonate masses in matrix and 12% medium distinct carbonate nodules in matrix; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 34% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.0.

Ecology

The ABLA/MARE11, Frisco Family ET represents lower elevation subalpine fir forests on calcareous soils along the eastern slope of the WRR. Subalpine fir lower than ~2750 m in the study area is restricted to cold air drainages and cooler, mesic, northerly slopes. The clay-rich soils have high available waterholding capacity, a factor that contributes to the maintenance of high levels of soil moisture well into the summer months. On calcareous soils, Rocky Mountain Douglas-fir and limber pine are the most important seral species (Bradley and others 1992). Oregon grape, which is tolerant of full sun and partial to deep shade, is often the only shrub species able to tolerate the intense shade experienced in the understory of climax stands of this ET (Uley 2006).

Mollisols are most commonly associated with soils in grassland and sagebrush communities (Nimlos and Tomer 1982). However, a handful of Mollisols occurred under north-facing conifer stands, sites more typical of Alfisols, including one sample site in the ABLA/MARE11, Frisco Family ET. The vegetation communities on north-facing forested Mollisols were typified by more open overstories and relatively high abundance of grass in the understories. The grassland influence at these sites may be associated with forest fire and represent the early stages of the transition between grassland and forest. Given sufficient time between disturbance events, a closing of the forest canopy, and acidification of the soils by conifer needles, the soils at these sites may lose any evidence of the grassland influence in the understory.

Succession

Sample sites in the ABLA/MARE11, Frisco Family ET fall within successional stages (D) or (E) described below. An herbaceous/shrub stage (A), which may include some limber pine regeneration, follows directly from a stand-replacing burn (Bradley and others 1992). In the absence of fire, the herbaceous/shrub stage is followed by a Rocky Mountain Douglas-fir and limber pine seedling and sapling stand (B). A fire of any severity at stage (B) will reset the successional pathway to the herbaceous/shrub stage. A Rocky Mountain Douglas-fir and limber pine pole stand, with subalpine fir regeneration follows the seedling and sapling stand (C) in the absence of fire. Low severity fires maintain the pole stand, while moderate severity fires at stage (C) typically escalate into severe fires and reset the successional pathway. In the continued absence of fire, the pole stand is followed by a mature limber pine and Rocky Mountain Douglas-fir stand with strong subalpine fir regeneration (D) and then by a mixed Rocky Mountain Douglas-fir, limber pine, subalpine fir stand (E). Low severity fires at stages (D) or (E) maintain each respective stage, while moderate severity fires favor the slightly more fire resistant Rocky Mountain Douglas-fir and lead to an open Rocky Mountain Douglas-fir forest with Rocky Mountain Douglas-fir regeneration (D1). Stage (D1) is maintained by low to moderate severity fires. In the absence of fire, stage (D1) progresses to stages (D) and (E). A climax stand (F) of mature subalpine fir with plentiful subalpine fir regeneration follows from stage (E) and is maintained by low severity burns or the absence of fire. Severe fires at stages (D), (D1), (E), and (F) completely reset the successional pathway.

Management considerations

The ABLA/MARE11, Frisco Family ET is highly productive and shows promise for timber harvest; however, the steep slopes sometimes associated with this ET may preclude access to logging equipment. Also, the clay-rich soils are at increased risk of compaction. Soil compaction can lead to reduced rates of water infiltration and lower soil volume, factors resulting in reduced root penetration and overall water availability (Meurisse and others 1991). Forest managers should (1) consider cable yarding as an alternative harvest technique on steep slopes, and (2) limit the number of logging roads developed in lower gradient stands and require equipment operators to remain on designated roads. Downed logs located away from roads may be retrieved using a cable and winch system attached to skidders.

Timber managers interested in targeting Rocky Mountain Douglas-fir over subalpine fir as a timber species may consider a moderate severity prescribed fire at successional stages (D) or (E), which will favor Rocky Mountain Douglas-fir over subalpine fir. However, forest managers should proceed with caution for two reasons: (1) low to moderate severity controlled burns in early seral stands can quickly escalate into severe stand-replacing burns, and (2) post-fire mortality may occur as a result of western spruce budworm, Douglas-fir beetle (*Dendroctonus pseudotsugae*), and/or wood borer outbreaks which typically follow light ground fires to moderate intensity burns. Since subalpine fir and Rocky Mountain Douglas-fir are a wind-dispersed species that regenerates most favorably in small canopy openings, silvicultural techniques should be used that leave suitable seed trees and result in small forest gaps, including individual tree selection or shelterwood cuts (Uchytil 1991a). The seed tree method is not generally recommended because of the susceptibility of subalpine fir to windthrow. Uneven-aged silviculture can be problematic because residual subalpine fir trees damaged during thinning operations are susceptible to attack by decay fungi. Deer trails were commonly observed in this ET. Following severe fire, this ET may provide moderate amounts of forage. However, forage production drops continually as stand age increases, and Oregon grape may be the only species with appreciable forage value in climax stands.

Lastly, where this ET is underlain by Gros Ventre Shale bedrock, landslide potential is high, especially following a wetter than normal winter/spring on steep (approximately >35%), recently burned slopes.

Similar ecological types

Ecological Type 1

Type: Douglas-fir/Oregon grape, Cloud Peak Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Frisco Family ET is subalpine fir, while the potential natural vegetation of the Cloud Peak Family ET is Douglas-fir.

Environmental differences: The two types differ in that the Frisco Family ET occurs at slightly higher elevations (avg. 2666 m) and experiences lower degree days (avg. 15720) and average annual temperature (avg. 1.6 ºC) than the Cloud Peak Family ET, which occurs at an average elevation of 2582 m and experiences higher degree days (avg. 17350) and average annual temperature (2.2 ºC).

Table 30—Summary of environmental variables for the ABLA/MARE11, Frisco Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,666	2,605	2,724
Slope (%)	34	26	47
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	647	632	671
Degree days	15,720	15,040	16,080
Frost-free days	19.3	19.1	19.5
Site water balance (mm/year)	-210	-240	-179
Average annual temperature (°C)	1.6	1.3	1.7
Total annual potential evapotranspiration (mm)	512	483	552
Summer radiation (KJ)	18,380	17,260	19,050
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	54	40	77
Clay (% in particle size control section)	20	16	22
pH (in particle size control section)	7.7	7.4	7.8
Available water capacity (mm/m)	58	30	76
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	3
Exposed bedrock	1	0	5
Gravel	4	2	5
Cobble	8	3	15
Stones	2	0	5
Boulders	0	0	0
Litter	39	25	55
Wood	11	5	20
Moss and lichen	2	1	2
Basal vegetation	29	25	40
Water	0	0	0

Table 32—Stand characteristics for the ABLA/MARE11, Frisco Family ET.

	Basal area		**Diameter at breast height (DBH)**		**Trees per hectare**	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m²/ha---		*-------Centimeters-------*			
ABLA	3.4	2.3-4.6	23.4	13.5-44.5	131	15-311
PICOL	3.4	2.3-4.6	18.3	15.2-23.6	143	126-163
PIFL2	4.6	2.3-9.2	17.8	10.4-24.1	227	101-420
PSMEG	12.6	6.9-23.0	37.8	18.0-55.9	153	42-212

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	19.6	17	51
PICOL	15.2	—	51
PIFL2	18.8	12	73
PSMEG	39.6	24	83

Table 31—Constancy/cover table for common plant species occurring in the ABLA/MARE11, Frisco Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Dominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	50	10	10	10
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	21	15	25
Subdominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	4	1	10
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	50	3	1	5
PIFL2	*Pinus flexilis*	Limber pine	100	6	5	10
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	3	1	5
PIFL2	*Pinus flexilis*	Limber pine	100	5	3	10
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	4	3	5
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	3	1	5
PIFL2	*Pinus flexilis*	Limber pine	50	6	1	10
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	2	1	5
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	Common juniper	100	7	1	20
MARE11	*Mahonia repens*	Oregon grape	100	3	3	3
SHCA	*Shepherdia canadensis*	Russet buffaloberry	100	12	1	20
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	Western yarrow	100	1	1	1
AGGL	*Agoseris glauca*	Pale agoseris	50	1	1	1
ANMA	*Anaphalis margaritacea*	Common pearly-everlasting	50	1	1	1
AQCO	*Aquilegia coerulea*	Colorado blue columbine	50	3	1	5
ARCO9	*Arnica cordifolia*	Heartleaf arnica	100	5	3	10
ASAUG	*Astragalus australis* var. *glabriusculus*	Indian milkvetch	50	3	3	3
CARO2	*Campanula rotundifolia*	Harebell	100	1	1	1
ERCO24	*Eremogone congesta*	Ballhead sandwort	50	1	1	1
FRSP	*Frasera speciosa*	Elkweed	100	2	1	5
FRVI	*Fragaria virginiana*	Virginia strawberry	50	2	1	3
GABO2	*Galium boreale*	Northern bedstraw	100	2	1	3
ORSE	*Orthilia secunda*	Sidebells wintergreen	50	1	1	1
OSDE	*Osmorhiza depauperata*	Bluntseed sweetroot	75	1	1	1
PHMU3	*Phlox multiflora*	Many-flowered phlox	50	1	1	1
POCO13	*Potentilla concinna*	Elegant cinquefoil	50	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	75	1	1	1
SYFO2	*Symphyotrichum foliaceum*	Alpine leafybract aster	75	1	1	1
TAOF	*Taraxacum officinale*	Common dandelion	75	1	1	1
Grasses:						
LEKI2	*Leucopoa kingii*	Spike-fescue	100	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	2	1	3
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	50	1		

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Subalpine Fir/Heartleaf Arnica-Cold Air Drainage, Hierro Family Ecological Type

Abies lasiocarpa/Arnica cordifolia-Cold Air Draininage, Hierro Family ET

ABLA/ARCO9-CAD, Hierro Family ET

N = 5

Distribution

The subalpine fir/heartleaf arnica-Cold Air Drainage, Hierro Family Ecological Type occurs along the eastern flank of the WRR within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs in the headwaters of Lime Kiln Gultch, Whiskey Creek, Blue Hole Creek, and Red Creek. In the southern study area, this ecological type occurs near the headwaters of a number of drainages, including (from northwest to southeast) Baldwin, Porcupine, Squaw, Elderberry, Crooked, Snow, and Cherry Creeks. This ET occurs along Sawmill Creek from the junction of Townsend Creek downstream to Crooked Creek. This ET also occurs along Canyon Creek from the junction of Spring Creek downstream to the Little Popo Agie River. It is a component of map unit 43L.

Environment

Aspect: North [3], north-northeast [1], north-northwest [1].

Landforms and Landscape Position: Footslopes and toeslopes.

Parent Materials: Mixed limestone and dolomite colluvium.

Parent materials are typically mixed limestone and dolomite colluvium. However, along Canyon Creek, parent materials were mixed limestone and dolomite colluvium over Flathead Sandstone residuum.

Bedrock: Cambrian Sandstone, Cambrian or Mississipian Limestone, Ordovician Dolomite.

Along Baldwin, Porcupine, Squaw, Sawmill, and Canyon Creeks, bedrock is Flathead Sandstone. Along South Fork Squaw, Elderberry, and Cherry Creeks, bedrock is Gallatin Limestone. At the headwaters of Snow Creek, bedrock is Bighorn Dolomite. At the headwaters of Crooked Creek, bedrock is Madison Limestone.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 57 to 65 cm.

Additional environment data summaries are provided in Table 33.

Potential natural vegetation

The potential natural vegetation for this ecological type is the subalpine fir/heartleaf arnica habitat type-heartleaf arnica phase (Steele and others 1983). Subalpine fir dominates all canopy layers. Rocky Mountain Douglas-fir is the major seral species on limestone and dolomite. On sandstone, lodgepole pine is the major seral species. Limber pine is sometimes present and represents a hold-over from early seral stages. Quaking aspen is almost always present in the understory canopy layers in scattered patches.

Shrub species are often scattered or completely lacking. Russet buffaloberry occasionally occurs at higher abundance (≥5%), in which case the vegetation would classify as the russet buffaloberry phase. Oregon grape was abundant (10%) at one early seral site dominated by lodgepole pine. Given enough time, Oregon grape will decline in abundance as subalpine fir achieves dominance and shades the understory.

In mature stands, subalpine fir forms a dense canopy layer, which significantly reduces sunlight penetration to the forest floor. Due to the intense shading by subalpine fir, the herbaceous layer is depauperate and extremely species poor. Heartleaf arnica is the most common species, followed by sidebells, greenflowered wintergreen, and bluntseed sweetroot. Ross' sedge is the most common graminoid. Sticky purple geranium is sometimes present, indicating the moist microenvironment experienced by this ecological type. Early seral stages of this type will often have a more diverse herbaceous layer, including harebell, Indian milkvetch, slender hawkweed, Virginia strawberry, bigleaf lupine, and sticky cinquefoil. Summaries of species constancy/cover and stand characteristics are provided in Tables 34 and 35, respectively.

Soils

Soils in the ABLA/ARCO9-CAD, Hierro Family ET are deep and carbonate rich, with a high degree of soil development, low to moderate coarse fragments (avg. 33%), and strong clay illuviation into subsurface soil horizons (avg. 31%). A thin (avg. 3 cm thick) litter layer occurs at the surface. A typical soil features an A/Bw/Bt horizonation. Some

soils may display a Btk-horizon below the Bt-horizon. One soil featured a 7-cm thick BE-horizon and a 16-cm thick Bt/E-horizon below a 26-cm thick A-horizon. Diagnostic soil horizons include an ochric epipedon (avg. 12 cm thick) and a thick argillic horizon (76 cm thick). Particle size classes included loamy-skeletal [2], fine-loamy [2], and clayey-skeletal [1]. Soils were Eutric Haplocryalfs [3], Inceptic Haplocryalfs [1], and Typic Haplocryalfs [1].

Typical pedon description

Soil Classification: Fine-loamy, mixed, superactive Eutric Haplocryalfs

Oi—0 to 2 cm: slightly decomposed plant material; abrupt wavy boundary.

Oe—2 to 6 cm: moderately decomposed plant material; abrupt smooth boundary.

A—6 to 10 cm: black (10YR 2/1) very fine sandy loam, very dark grayish brown (10YR 3/2), dry; 54% sand; 14% clay; weak medium platy structure, and weak fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common very fine and fine and common medium pores; 2% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; moderately acid, pH 5.7; clear wavy boundary.

Bw—10 to 19 cm: brown (10YR 4/3) sandy clay loam, brown (10YR 5/3), dry; 60% sand; 23% clay; weak coarse subangular blocky structure, and moderate thick platy structure; friable, slightly hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very coarse roots and common very fine roots; common fine and common medium and common coarse and common very coarse and common very fine pores; 1% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.4; clear smooth boundary.

Bt1—19 to 49 cm: brown (10YR 4/3) sandy clay loam, brown (10YR 5/3), dry; 54% sand; 22% clay; weak coarse subangular blocky structure, and moderate medium subangular blocky structure; friable, moderately hard, moderately sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots and common very coarse roots; common very fine and fine and common medium and common coarse and common very coarse pores; 3% patchy faint clay films on surfaces along root channels and 5% patchy faint clay films on all faces of peds; 1% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 3% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; moderately acid, pH 5.6; abrupt smooth boundary.

Bt2—49 to 62 cm: dark yellowish brown (10YR 4/4) very bouldery sandy clay loam, yellowish brown (10YR 5/4), dry; 63% sand; 25% clay; moderate coarse subangular blocky structure, and moderate very fine subangular blocky structure; firm, hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots; common very fine and fine and common medium pores; 52% patchy distinct clay films on all faces of peds and 52% patchy faint clay films on all faces of peds; 3% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 6% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 9% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 36% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; slight effervescence; neutral, pH 7.1; Ped and Void: Clay films are both faint and distinct.; clear smooth boundary.

Bt3—62 to 82 cm: yellowish brown (10YR 5/4) extremely bouldery sandy clay loam, light yellowish brown (10YR 6/4), dry; 70% sand; 23% clay; moderate medium subangular blocky structure, and moderate very fine subangular blocky structure; firm, moderately hard, moderately sticky, moderately plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 16% patchy faint clay films on top surfaces of rock fragments and 31% patchy distinct clay films on all faces of peds; 5% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 12% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 56% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; very slight effervescence; neutral, pH 7.2; Ped and Void: Clay films are both faint and distinct.; gradual wavy boundary.

Btk—82 to 104 cm: brown (10YR 4/3) extremely bouldery sandy clay loam, pale brown (10YR 6/3), dry; 76% sand; 22% clay; weak fine subangular blocky structure; friable, moderately hard, moderately sticky, slightly plastic; common fine roots and few medium roots and common coarse roots and common very fine roots; common fine and few medium and common coarse and common very fine pores; patchy faint carbonate coats on rock fragments and 3% patchy faint clay films on all faces of peds; 4% fine faint carbonate masses in matrix; 6% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 27% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 52% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; slight effervescence; slightly alkaline, pH 7.4.

Ecology

The ABLA/ARCO9-CAD, Hierro Family ET represents the low elevation extreme of subalpine fir forests on calcareous soils along the eastern slope of the WRR. These forests occur in a relatively narrow strip (≤250 m) along footslopes and toeslopes of headwater drainages in the sedimentary formations. Dense, cold air is funneled into the drainages associated with this ET, where it flows under the force of gravity to lower elevations. This cold air drainage effect extends the altitudinal range of subalpine fir to elevations lower than it would normally tolerate in upland environments. The clay-rich soils have high available water holding capacity, which helps maintain high soil moisture well into the summer months. Also, stands located at the headwaters of small drainages on limestone and dolomite bedrock were positioned on the leeward side of the Gallatin Limestone outcrops. During the winter months, snow accumulates in these areas, and remains on the ground until mid-summer (Wells, A.F., pers. observation).

Alfisols are soils that exhibit the translocation and accumulation of clay minerals in subsurface horizons and that lack either the high base saturation and/or the accumulation of organic carbon typical of Mollisols (Soil Survey Staff 2003). The zone of clay accumulation is termed an argillic horizon and is marked by a significantly greater percentage of clay than overlying soil material and evidence of clay illuviation, including clay films and clay bridges. Primary to the development of Alfisols is the dispersion and translocation of clay minerals from higher in the soil profile. Dispersion of clays is largely dependent on the electrolyte concentration of the soil (Birkeland 1999). Clay translocation requires the dispersion of clay minerals and a transport medium such as water. Clay particles in soils high in electrolytes, such as those derived from carbonate rich parent materials, tend to be attracted to one another and cannot be dispersed and translocated (Anderson and others 1975). In soils rich with carbonates, clay minerals typically do not disperse until after the carbonates have been leached from the soil unless the electrolyte concentration of the soil is reduced. Conifer needles tend to decrease soil pH (Daubenmire 1959). Deep accumulations of snow can decrease the pH of meltwater and, in turn, the pH of the soil beneath by trapping CO_2 produced by organisms and soil and forming carbonic acid, a weak acid formed by the combination of water and carbon dioxide (Seppälä 2004). Reduced electrolyte concentrations due to the combined effect of conifer needles and acidification of meltwater, combined with the overall high availability of water at these sites, should encourage the dispersion and translocation of clays and the development of the thick argillic horizons typical of soils in this ET.

Succession

The majority of the sample sites in the ABLA/ARCO9-CAD, Hierro Family ET were located on limestone or dolomite parent materials where Rocky Mountain Douglas-fir is the major seral species. Sample sites on limestone and dolomite fell within successional stages (E) or (F) described below for Rocky Mountain Douglas-fir seral stands. One sample site was located on limestone and dolomite colluvium over Flathead Sandstone residuum, and lodgepole pine was the major seral species. This sample site fell within successional stage (D) described below for lodgepole pine seral stands.

At sites where Rocky Mountain Douglas-fir is the major seral species, an herbaceous/shrub stage (A), which may include some limber pine regeneration, follows directly from a stand-replacing burn (Bradley and others 1992). In the absence of fire, the herbaceous/shrub stage is followed by a Rocky Mountain Douglas-fir, limber pine, quaking aspen seedling and sapling stand (B). A fire of any severity at stage (B) will reset the successional pathway to the herbaceous/shrub stage. In a mixed Rocky Mountain Douglas-fir, limber pine, and quaking aspen pole stand with subalpine fir, regeneration follows the seedling and sapling stand (C) in the absence of fire. Low-severity fires maintain the pole stand, while moderate severity fires at stage (C) typically escalate into severe fires and reset the successional pathway. In the continued absence of fire, quaking aspen begins to decline as the understory becomes shaded, and the pole stand is followed by a mature limber pine and Rocky Mountain Douglas-fir stand with strong subalpine fir regeneration (D), and then by a mixed Rocky Mountain Douglas-fir, limber pine, subalpine fir stand (E). Low-severity fires at stages (D) or (E) maintain each respective stage, while moderate-severity fires favor the slightly more fire resistant Rocky Mountain Douglas-fir and lead to an open Rocky Mountain Douglas-fir forest with Rocky Mountain Douglas-fir regeneration (D1). Stage (D1) is maintained by low-to-moderate-severity fires. In the absence of fire, stage (D1) progresses to stages (D) and (E). A climax stand (F) of mature subalpine fir with plentiful subalpine fir regeneration follows from stage (E) and is maintained by low-severity burns or the absence of fire.

Severe fires at stages (D), (D1), (E), and (F) completely reset the successional pathway.

At sites where lodgepole pine is the major seral species, an herbaceous/shrub stage (A), which may include quaking aspen sprouts, follows directly from a stand-replacing burn (Bradley and others 1992). The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven aged lodgepole pine and quaking aspen seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole pine and quaking aspen stand, with subalpine fir seedlings in the understory (C), and then by a mature lodgepole pine stand, with understory subalpine fir (D). Low to moderate severity fires at stages (C) and (D) will maintain the stand at each respective stage, while severe fire will completely reset the successional pathway. With a continued lack of fire, quaking aspen begins to decline, and a mixed subalpine fir and lodgepole pine stand develops (E). A low intensity fire at stage (E) will maintain the mixed stand, while a moderate severity fire will return the stand to stage (D). Lodgepole pine will eventually drop out of the overstory and be replaced by subalpine fir, resulting in a climax stand of mixed subalpine fir with strong subalpine fir regeneration (F). Severe fires at stages (E) and (F) will completely reset the successional pathway.

Management considerations

The ABLA/ARCO9-CAD, Hierro Family ET is highly productive and shows the most promise for timber harvest at successional stages (D) or (E) where Rocky Mountain Douglas-fir is the major seral species, and stages (C), (D), or (E) where lodgepole pine is the major seral species. Since these stands are typically narrow and linear, timber harvest should be planned to coincide with the harvest of Rocky Mountain Douglas-fir, lodgepole pine, or subalpine fir stands located on adjacent backslopes in order to maximize the harvest. Also, the clay-rich soils are at increased risk of compaction by heavy logging equipment. Soil compaction can lead to reduced rates of water infiltration and lower soil volume, factors resulting in reduced root penetration and overall water availability (Meurisse and others 1991). Forest managers should limit the number and length of logging roads developed in this ET and require equipment operators to remain on designated roads. Downed logs located away from roads may be retrieved using a cable and winch system attached to skidders.

Since subalpine fir and Rocky Mountain Douglas-fir are wind-dispersed species that regenerate most favorably in small canopy openings, silvicultural techniques should be used that leave suitable seed trees and result in small forest gaps, including individual tree selection or shelterwood cuts (Uchytil 1991a). The seed tree method is not generally recommended because of the susceptibility of subalpine fir to windthrow. Uneven-aged silviculture can be problematic because residual subalpine fir trees damaged during thinning operations are susceptible to attack by decay fungi. Timber harvest is not recommended in climax stands due to the prevalence of stem, butt, and root rot. Climax stands are also susceptible to western spruce budworm and western balsam bark beetle attack. Longhorned beetles were commonly observed in this ET. Prescribed fire can be used to control insect infestations, reduce fuels, and renew older stands suffering from decay fungi or fir broom rust. Fire prescriptions should give particular attention to the proximity of seed trees to the burned area following fire. Climax stands of this ET provide important bedding areas for wild ungulates due to the moderate slope gradient and close proximity of adjacent foraging grounds. Snags in this ET provide feeding and nesting opportunities for cavity nesting birds and roosting sites for bats. Following severe fire, this ET may provide moderate amounts of forage. However, forage production drops continually as stand age increases.

Similar ecological types

Ecological Type 1

Type: NONE

Table 33—Summary of environmental variables for the ABLA/ARCO9, Hierro Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,637	2,480	2,743
Slope (%)	18	10	31
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	625	571	652
Degree days	16,500	15,750	18,060
Frost-free days	19.7	19.3	20.5
Site water balance (mm/year)	-229	-286	-185
Average annual temperature (°C)	1.8	1.5	2.5
Total annual potential evapotranspiration (mm)	581	567	600
Summer radiation (KJ)	19,390	18,730	20,690
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	33	14	47
Clay (% in particle size control section)	31	22	40
pH (in particle size control section)	6.7	6.1	7.1
Available water capacity (mm/m)	102	58	135
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	0	1	3
Exposed bedrock	1	0	5
Gravel	1	0	5
Cobble	2	0	5
Stones	1	0	3
Boulders	0	0	0
Litter	54	25	70
Wood	20	15	25
Moss and lichen	2	0	4
Basal vegetation	14	0	20
Water	0	0	0

Table 34—Constancy/cover table for common plant species occurring in the ABLA/ARCO9, Hierro Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	80	20	10	35
PICOL	*Pinus contorta* var. *latifolia*	Lodgepole pine	60	10	1	25
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	40	2	1	3
Subdominant overstory trees:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	12	5	15
POTR5	*Populus tremuloides*	Quaking aspen	60	3	1	5
Saplings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	10	3	25
Seedlings:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	10	3	20
POTR5	*Populus tremuloides*	Quaking aspen	60	2	1	3
Shrub:						
MARE11	*Mahonia repens*	Oregon grape	40	6	1	10
SHCA	*Shepherdia canadensis*	Russet buffaloberry	60	5	1	10
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	40	2	1	3
Forbs:						
ARCO9	*Arnica cordifolia*	Heartleaf arnica	100	7	3	15
CARO2	*Campanula rotundifolia*	Harebell	40	2	1	3
CHAN9	*Chamerion angustifolium*	Fireweed	40	1	1	1
GABO2	*Galium boreale*	Northern bedstraw	40	2	1	3
GEVI2	*Geranium viscosissimum*	Sticky purple geranium	60	2	1	3
ORSE	*Orthilia secunda*	Sidebells wintergreen	60	1	1	1
OSDE	*Osmorhiza depauperata*	Bluntseed sweetroot	60	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	40	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 35—Stand characteristics for the ABLA/ARCO9, Hierro Family ET.

Species	Basal area		Diameter at breast height (DBH)		Trees per hectare	
	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
ABLA	26.0	4.6–45.9	25.1	13.7–53.1	731	212–988
PICOL	8.0	2.3–13.8	18.5	13.7–21.8	324	74–576
PIEN	2.3	—	49.5	—	12	—
PIFL2	6.9	—	25.7	22.6–29.0	136	—
POTR5	2.3	—	18.5	17.8–19.3	170	—

Species	Site tree averages		
	DBH	Height	Age
	Centimeters	*Meters*	*Years*
ABLA	31.8	30	107
PICOL	21.8	15	120
PIEN	—	—	—
PIFL2	29.0	19	—
POTR5	17.8	21	—

Miscellaneous Subalpine Fir Types

Subalpine Fir/Gooseberry Currant, Cranbay Family Ecological Type

Abies lasiocarpa/Ribes montigenum, Cranbay Family Ecological Type

ABLA/RIMO2, Cranbay Family ET

N = 1

The subalpine fir/gooseberry currant, Cranbay Family Ecological Type occurs in the northern WRR within the granitic subalpine zone of Chapman and others (2004). This ET occurs along the upper extent of U-shaped glacial valleys on lateral glacial moraines. It is a component of map unit 327S. This ET was observed in the upper Dinwoody Creek valley in the northern portion of the study area on sheltered backslope and footslope positions at elevations between 2900 and 3100 m. Parent materials were mixed migmatite and gneiss glacial till. Soils were deep, fine-loamy Inceptic Haplocryalfs.

Potential natural vegetation of this ET is the subalpine fir/gooseberry currant habitat type-gooseberry currant phase (Steele and others 1983). Subalpine fir and Engelmann spruce share dominance in the overstory. Subalpine fir seedlings are always present and vigorously reproducing. Gooseberry currant is prolific throughout the understory. The otherwise depauperate understory includes a variety of mesic forbs, including tall ragwort, Colorado blue columbine, tall fringed bluebells, thickstem aster, sidebells wintergreen, and heartleaf arnica. Graminoids may include Ross' sedge, spike trisetum, and Cusick's bluegrass.

Snow accumulated on the steep, rocky slopes and cliffs above these lateral moraines melts slowly throughout the summer. Water from the melting snow flows down the cliffs in small rivulets and forms melt-water drainages that dissect these lateral moraines. Soil moisture in this ET remains relatively high throughout the summer due to the melt-water from these small drainages. The ABLA/RIMO2, Cranbay Family ET differs environmentally from the ABLA/RIMO2, Elting Family ET in that the former occurs as continuous forests at lower elevations below timberline, while the later occurs as tree islands at or near timberline.

Subalpine Fir/Grouse Whortleberry, Swapps Family Ecological Type

Abies lasiocarpa/Vaccinium scoparium, Swapps Family Ecological Type

ABLA/VASC, Swapps Family ET

N = 2

The subalpine fir/grouse whortleberry, Swapps Family Ecological Type occurs throughout the WRR within the granitic subalpine zone of Chapman and others (2004). This ET occurs along the upper extent of U-shaped glacial valleys on lateral glacial moraines. It is a component of map unit 327S. This ET occurred near Sweetwater Gap and in the North Fork Popo Agie drainage at elevations between 3000 and 3200 m. Parent materials were granodiorite or quartz monzonite glacial till. Soils were moderately deep to compacted till, fine-loamy, and loamy-skeletal Inceptic Haplocryalfs.

Potential natural vegetation of this ET is the subalpine fir/grouse whortleberry habitat type grouse whortleberry phase (Steele and others 1983). Subalpine fir and Engelmann spruce share dominance in the overstory. Subalpine fir seedlings are always present and vigorously reproducing. Engelmann spruce and whitebark pine seedlings also occur in the understory at low abundance. Grouse whortleberry is prolific throughout the understory, forming a dense, low shrub cover. Forbs and graminoids are typically scattered and may include thickstem aster, heartleaf arnica, fireweed, and slender hawkweed. Common graminoids include Ross' sedge and spike trisetum. The ABLA/VASC, Swapps Family ET differs from the ABLA/VASC, McCall Family ET in that the former features relatively clay-rich Alfisols, while the later features less well-developed Inceptisols.

Whitebark Pine Series

Principal Species Descriptions

Whitebark Pine

Pinus albicaulis Engelm.

Whitebark pine is a small- to medium-sized, five-needle pine found in high elevation forests from the subalpine to timberline. Whitebark pine superficially resembles limber pine in its growth habit, reaching between 12 to 18 m in height, with wide-spreading, upswept branches (Howard 2002). While the geographic range of limber and whitebark pine overlap to some degree, especially in the central and northern Rocky Mountains, the two species have disparate geographic ranges to the south and west. The altitudinal range of limber and whitebark pine overlaps to a small degree but is largely disparate. Where the two species co-occur geographically, whitebark pine inhabits higher elevations than limber pine.

The geographic range of whitebark pine is split into two distinct distributions, the first following the Rocky Mountains from eastern British Columbia and western Alberta southeast through western Montana, northern and central Idaho, and into northwestern Wyoming, and the second following the Coast Range of British Columbia, south through the Cascade Range, and into the Klamath and Sierra Nevada Mountains of California (Arno and Hoff 1990). In Wyoming, the WRR populations represent the southeasterly extent of the geographic range of whitebark pine in the Rocky Mountains. In the Pacific Northwest, whitebark pine is limited to dry, inland slopes of the Coast and Cascade Ranges and is absent from the wettest areas, including Vancouver Island. Whitebark pine occurs in the Olympic Mountains of Washington State where it is limited to peaks in the northeast rain shadow zone. Aside from this general distribution, whitebark pine occurs in the Blue and Wallowa Mountains of northeastern Oregon and several isolated ranges in northeastern California, south-central Oregon, and northern Nevada.

The climate of whitebark pine ecosystems is typically cold, windy, snowy, and moist relative to limber pine (Arno and Hoff 1990). In the Pacific Northwest, the climate has a strong maritime influence resulting in more moderate temperatures and higher precipitation, while the Rocky Mountains exhibit a continental climate with cold, harsh winters and hot, dry summers. In moist mountain ranges, whitebark pine is found predominantly on warm, dry slopes and ridgelines. In dry, semiarid mountain ranges whitebark pine shifts to cooler exposures and moist slopes. In January, across the geographic range of whitebark pine, the average daily temperature ranges from a nightly low of -11 °C (-14 to -8 °C) to a high of -1 °C (-3 to 1 °C) (Weaver 1990). Some of the coldest winter temperatures in whitebark pine forests have been reported in western Wyoming where average daily temperatures in January range between -18 and -5 °C, and record lows have been recorded as low as -44 °C. In July across the geographic range of whitebark pine, average daily temperatures range from a low of 4 °C (3 to 5 °C) to high of 21 °C (19 to 22 °C). Hard frosts are common into May and June and uncommon to rare in July and August. Mean annual precipitation is between 600 and 1000 mm in semi-arid mountains of Wyoming, southwestern Montana, central Idaho, and Nevada and between 900 and 1800 mm in mountains of the Pacific Northwest (Arno and Hoff 1990). Snowpack begins accumulating in October and is at a maximum by April. Snowpack in whitebark pine stands of the central and northern Rockies ranges between 60 and 125 cm and between 250 and 300 cm in the Pacific Northwest. However, redistribution of snow by wind often makes it difficult to determine the amount of effective precipitation received in whitebark pine forests.

Whitebark pine is similar to many subalpine tree species in that the elevation distribution shifts upward as latitude and/or precipitation decreases. In the Coast Range of British Columbia, the Olympic Mountains in Washington, and the western slope of the Cascade Range in Washington and northern Oregon, whitebark pine is a minor forest component occurring on exposed sites near timberline between 1,580 and 2,130 m (Arno and Hoff 1990). On the eastern slope of the Cascade Range in Washington and northern Oregon, both slopes of the Cascade Range in southern Oregon and northern California, and the Sierra Nevada Mountains, whitebark pine is a major forest component, occurring in subalpine forests and near timberline at elevations between 1,620 and 2,440 m, 2,440 and 2,990 m, and 3,050 and 3,510 m, respectively. In the Rocky Mountains of British Columbia and Alberta, whitebark pine is a minor component of subalpine forests and occurs mainly at exposed sites near timberline between 1,980 and 2,290 m. Whitebark pine is a major forest component of subalpine forests and timberline in Montana, Idaho, and Wyoming. Whitebark pine occurs at elevations between 1,800 and 2,500 m in northwestern Montana, 2,130 and 2,830 m in west-central Montana, and 2,440 and 3,200 m in western Wyoming.

The soils of whitebark pine forests are typically weakly developed, shallow (0–50 cm) to moderately deep (50–100 cm), coarse-textured, rocky, and acidic. Soils in whitebark pine forests are derived from a variety of parent materials, including limestone, dolomite, shale, siltstone, sandstone, quartzite, quartz monzonite, quartz diorite, gneiss, basalt, metasedimentary rocks, volcanic ash, and glacial till (Hansen-Bristow and others 1990). Weaver and Dale (1974) and Steele and others (1983) reported that in western Montana, eastern Idaho, and northwestern Wyoming, whitebark pine is virtually absent from soils derived from calcareous parent materials, apparently preferring coarse-grained, non-calcareous soils in this region. Shallow, residual soils typically support pure stands of whitebark pine, while on deeper soils, in glacial till or colluvium, whitebark pine typically occurs in mixed stands with subalpine fir, lodgepole pine, and/or Engelmann spruce. Whitebark pine is intolerant of prolonged soil saturation.

Whitebark pine is a monoecious conifer with female cones located near the tip of the crown branches and male cones developing throughout the crown on the current year's growth (Arno and Hoff 1990). The maturation process of cones requires two years, a trait typical of pines (*Pinus* spp.) (Howard 2002). Cone production may begin when individual whitebark pine reach 20 to 30 years old; however, full cone production is not achieved until 60 to 100 years. In northwestern Wyoming, northeastern Idaho, and southwestern Montana, cone production is characterized by two to three large cone crops per decade interspersed with small cone crops. Pollination occurs in late June at low to mid-elevations and in the first two weeks of July at higher elevations (Arno and Hoff 1990). The purplish, fleshy, small- to medium-sized (5 to 8 cm), egg-shaped cones house large, heavy, wingless seeds. When mature, the cones turn brownish and disintegrate on the tree. Unlike the cones of limber pine, which fall to the ground intact when mature, whitebark pine cones disintegrate on the tree, and intact cones are difficult to find on the ground immediately surrounding whitebark pine trees. As previously mentioned, whitebark and limber pine have similar growth-forms making it difficult to distinguish between the two species. Based on morphology, the differences in cone coloration, size, and ability to remain intact when mature are often the best means of distinguishing between whitebark and limber pine.

Similar to limber pine, whitebark pine is a bird-dispersed species sharing a mutualistic relationship with the Clark's nutcracker. Throughout late summer and fall, the Clark's nutcracker caches pine seeds for use during the winter months. An individual may transport up to 125 seeds at one time to destinations up to 22 km away from the parent tree (Vander Wall and Balda 1977). The Clark's nutcracker prefers to cache seeds in areas of low snow accumulation where snows melt earlier in the winter, including south-facing sites and windward slopes. About 80% of the approximately 20,000 to 30,000 seeds per ha that a single nutcracker might cache in one season are actually retrieved and consumed, leaving 20% to be eaten by rodents or germinate (Lanner and Vander Wall 1980; Schoettle and Rochelle 2000).

Whitebark pine seeds are often cached by the Clark's nutcracker before they are fully developed (Howard 2002). The cached seeds continue to mature for two or more years. Once the seeds are mature, germination occurs only after the seeds have been subjected to prolonged periods of cold weather and weathering of the seedcoat. Seedbeds must be moist for a significant period of time (≥four days) following germination in order to ensure success of the seedling. Whitebark pine is one of a few seed banking pines in North America, and as such good seedling establishment may occur even if the previous year cone crop was poor. Seedling establishment is most successful on sites with bare mineral soil and is especially favorable following severe burns.

Whitebark pine features single- and multi-stem forms (Howard 2002). The single-stem form occurs more often in mixed subalpine forests below timberline, while the multiple-stem form is more prevalent at or near timberline. The multiple-stem form results when clusters of seedlings germinate from Clark's nutcracker seed caches. Above timberline, whitebark pine features a krummholtz form and may reproduce by layering.

The successional status of whitebark pine ranges from minor seral to climax depending upon the location of forested stands relative to tree line (Howard 2002). Whitebark pine is a minor seral species in lower subalpine forests, a major seral species in upper subalpine forests, a co-climax species at lower timberline, and a climax species at upper timberline, forming even-aged, monocultural stands. Whitebark pine is often the first species to colonize burned sites. In general, the shade tolerance of whitebark pine may be rated as moderate (McCaughey and Schmidt 1990). However, the shade tolerance of whitebark pine increases with age from highly to moderately intolerant at the seedling and sapling stages to moderately tolerant at later developmental stages. At later developmental stages, whitebark pine is considered less shade tolerant than subalpine fir and Engelmann spruce but more shade tolerant than limber and lodgepole pine.

The fire tolerance of whitebark pine seedlings and saplings is very low due to thin resin-filled bark, and mortality may occur from even low severity surface fires (Howard 2002). Severe fires, especially those that reach the overstory, are detrimental to adult whitebark pine. However, three factors are important in enhancing the ability of whitebark pine to survive burns and thrive following fire. First, the bark thickness of adult trees ranges between that of ponderosa pine bark (thick) and lodgepole pine bark (thin) and is considered moderately thick. The moderately thick bark allows mature whitebark pine to survive low- to moderate-severity fires. Second, fuels are often limited in pure whitebark pine stands due to low productivity, often resulting in patchy, mixed severity fires. Large, refugia trees often survive in areas where fire was absent or of low severity, thus providing a seed source for adjacent burned areas. Lastly, the Clark's nutcracker is highly efficient at distributing and caching seeds at newly burned sites.

Fire regimes in whitebark pine ecosystems are mixed severity with widely ranging fire intensities and frequencies (Howard 2002). Fire return intervals range between 30 and 350+ years. Late successional species, including subalpine fir and Engelmann spruce, dominate in areas with high fire return intervals. In mixed, mid-elevation subalpine forests where whitebark pine is a seral species, and at lower timberline forests where whitebark pine is a co-climax species, the fire return intervals of those species co-occurring with whitebark pine are relevant. At timberline, where whitebark pine forms open canopy, even-aged, monocultural stands, fires are typically patchy and mixed severity due to a limited fuel supply and large widely spaced trees. In general, forest fire is an important factor in maintaining whitebark pine throughout subalpine and timberline ecosystems.

Across the central and northern Rocky Mountains, whitebark pine is susceptible to a variety of insect pests and diseases, the most prominent of which are described below. Of the insect pests, mountain pine beetle has been the most damaging to whitebark pine (Arno and Hoff 1990). Large epidemics occur periodically, killing most of the whitebark pine in the infested area. The adults and larvae of the mountain pine beetle feed on the phloem layer of the inner bark, eventually girdling the tree. Trees attacked by mountain pine beetle are inoculated with blue stain fungi, and individuals not killed directly by the beetle later succumb to the fungi (Hagle and others 2003). Mountain pine beetle epidemics often begin in lower elevation lodgepole pine stands (Eggers 1990). Managers concerned with mountain pine beetle epidemics in whitebark pine forests may want to consider monitoring adjacent lower elevation lodgepole pine stands for signs of beetle activity.

Pine engraver beetles (*Ips* spp.) bore through the outer bark and feed in the phloem layer, introducing blue stain fungi along the way (Hagle 2003). Top-kill is a common symptom of trees attached by pine engraver beetles. When populations of pine engraver beetles are high, whitebark pine death may ensue. Pine cone beetle (*Conophthorus ponderosae*) and western conifer seed bug (*Leptoglossus occidentalis*) feed on the cones and developing seeds. White pine blister rust (*Cronartium ribicola*) is the leading cause of whitebark pine death (Arno and Hoff 1990). Introduced from Eurasia, the species is lethal to whitebark pine (Hagle and others 2003). White pine blister rust causes branch and stem cankers, which eventually girdle the branches and/or stem, causing top kill and eventually death. White pine blister rust is especially prevalent in areas where gooseberries and currants (*Ribes* spp.), obligate alternate hosts of white pine blister rust, occur. Recently, two previously unknown alternate hosts of white pine blister rust were discovered in northern Idaho (McDonald and others 2006). Sickletop lousewort (*Pedicularis racemosa*) and giant red Indian paintbrush (*Castilleja miniata*) were confirmed as alternate hosts of white pine blister rust through a combination of DNA testing, scanning electron microscopy, and laboratory inoculations. Zambino and others (2006) suggested that the utilization of non-*Ribes* host species by white pine blister rust is likely not limited to whitebark pine forests in northern Idaho. They further speculate that non-*Ribes* alternate hosts of white pine blister rust may be of particular importance for spreading the rust given the prevalance of the non-*Ribes* host species in high elevation environments. Zambino and others (2006) advise that additional studies are required to quantify the degree to which different populations of white pine blister rust across the western United States utilize non-*Ribes* alternate hosts, and develop effective management and restoration strategies for whitebark pine. Additional studies may include surveys to assess the occurrence and prevalence of blister rust on non-*Ribes* species, collection and preservation of infected specimens, and experiments designed to tease out the complex interactions between management activities and non-*Ribes* alternative hosts. See Zambino and others (2006) for more details.

Whitebark pine is susceptible to a variety of root, butt, and stem diseases, including red belt fungus (*Fomitopsis pinicola*) and red ring rot (*Phellinus pini*) (Hagle and others 2003). The pine needle cast (*Lophodermella arcuata*) is a fungus that attacks and kills primarily one-year-old foliage. The result is a loss in growth rate and, in smaller trees, death. Another fungus, brown felt blight (*Neopeckia coulteri*) develops on needles that are buried in snow and remain moist for prolonged periods of time in the spring. The infected needles become matted together by a dark brown mat of mycelium and eventually are killed. Brown felt blight is rarely lethal. Lodgepole pine and limber pine dwarf mistletoes (*Arceuthobium americanum* and *A. cyanocarpum*, respectively) are common parasites of whitebark pine. "Witches brooms" form on infected trees. Top kill, stem cankers, and swellings are common symptoms of dwarf mistletoe infection. Trees infected by dwarf mistletoe are also more susceptible to mountain pine beetle attack.

Whitebark pine is declining at an alarming rate across the majority of its geographic distribution (Howard 2002). The decline is due primarily to a combination of fire exclusion, mountain pine beetles, and white pine blister rust. Restoring the natural fire regime is perhaps the most important management action that can be taken to help maintain and promote the establishment of whitebark pine. A major proportion of whitebark pine is located in remote, wilderness settings where controlled burns may be logistically and fiscally difficult. One means of fire management in wilderness settings is to allow natural fires ignited in wilderness areas to burn while monitoring the fire to ensure the safety of private residences adjacent to national forests. If the choice is made to use management-ignited fires in whitebark pine forests, light ground fires and low to moderate severity burns help maintain whitebark pine forests by killing seedlings of competing species. Stand replacing burns can be used to open up large areas of bare mineral soil where whitebark pine seeds may be readily planted by Clark's nutcrackers. However, if stand replacing burns are used as a management tool in whitebark pine forests, careful consideration should be given to the availability of adjacent whitebark pine to act as seed trees. Also, stand-replacing burns should not be used in areas where whitebark pine is in serious decline (e.g., northern Idaho and northwestern Montana). In these areas, stand-replacing burns risk the destruction of individual whitebark pines genetically resistant to white pine blister rust. The best time to conduct a prescribed burn is following an early frost/snowfall in the fall of the year. Managers may consider a post-fire thinning treatment to remove more shade-tolerant species and promote whitebark pine.

Although managing whitebark pine forests for timber production is not recommended, a variety of silvicultural treatments may be used to promote whitebark pine. Both even-aged, including clear-cutting, seed tree, and shelterwood, and uneven-aged, including group selection and singletree, are recommended (Eggers 1990). The best treatment at a particular site depends on the degree of exposure of the site to wind. Across a gradient of slope exposure from the most to the least exposed, the treatments should be considered as follows: clear-cutting, seed tree, shelterwood, group selection, and singletree. The retention of healthy, wind-firm, seed trees with phenotypic resistance to blister rust is fundamentally important in promoting regeneration following even-aged treatments. Seed production may be increased by selectively cutting trees to increase spacing, thus producing trees with a higher proportion of crowns fully exposed to sunlight.

Whitebark pine seeds are an integral part of the diet of black and grizzly bears, providing an important source of calories for bears preparing for hibernation (Howard 2002). Red squirrels also feed heavily on whitebark pine seeds, storing them in middens on the forest floor. As previously mentioned, Clark's nutcrackers feed heavily on whitebark pine seeds. The depauperate herbaceous layer typical of whitebark pine forests in the central Rocky Mountains are of little forage value for large wild ungulates. Whitebark pine forests provide valuable thermal cover for wild ungulates, especially at upper elevations where other tree species are generally lacking (Arno and Hoff 1990). Large, hollow snags of whitebark pine provide feeding and nesting opportunities for cavity nesting birds. Historically, Native Americans utilized whitebark seeds as a secondary food source.

Krummholz, Klootch Family Ecological Type

Krummholz, Klootch Family ET

N = 3

Distribution

The Krummholz, Klootch Family Ecological Type occurs in the northern and southern study areas within the alpine zone ecoregion of Chapman and others (2004). This ET is a component of map unit 304L. This ET occurs above timberline near the boundary between the alpine tundra and timberline forests. This ET typically occurs in microsites suitable for the establishment of tree seedlings, including gentle concavities and sheltered slopes. Trees in these forested stands are stunted from extreme cold temperatures and strong winter winds, resembling more of a shrub than a tree.

Environment

Aspect: East-southeast [1], north-northwest [1], south [1].

Landforms and Landscape Position: Upper backslopes and shoulders.

Parent Materials: Colluvium, colluvium over granitic glacial till.

In the southern portion of the WRR, including Wind River Peak, Ice Lakes, and areas to the south, parent material tends to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, parent material tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including the areas surrounding Ram, Goat, and Burro Flats; Horse Ridge; Brown Cliffs; and Dennis Lake, parent materials tend to be migmatite and/or gneiss.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss and migmatite.

In the southern portion of the WRR near Wind River Peak and Ice Lakes, bedrock tends to be granodiorite of the Louis Lake Pluton. In the southern portion of the WRR in the areas north of the North Fork Popo Agie River, bedrock tends to be porphyritic quartz monzonite. In the northern portion of the WRR, including the areas surrounding Ram, Goat, and Burro Flats; Horse Ridge; Brown Cliffs; and Dennis Lake, bedrock tends to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 77 to 86 cm.

Additional environment data summaries are provided in Table 36.

Potential natural vegetation

The potential natural vegetation of this ecological type is the subalpine fir-whitebark pine krummholz habitat type. Trees in these forested stands are stunted from extreme cold temperatures and strong winter winds. Subalpine fir and whitebark pine are the projected climax tree species and occur in the overstory as co-dominants. Engelmann spruce is occasionally found in the overstory canopy layer.

A variety of subalpine and alpine willow species may occur in this habitat type, including grayleaf, arctic, shortfruit, and snow willows. Grayleaf willow is commonly found growing along melt-water channels. Pink mountainheath and grouse whortleberry often occur on drier microsites.

The herbaceous layer is especially species rich. Common forbs include alpine sagebrush, ballhead sandwort, subalpine fleabane, Ross' avens, American bistort, wormleaf stonecrop, and manyray goldenrod. Common graminoids include spike trisetum, Rocky Mountain fescue, alpine timothy, northern singlespike sedge, and spike woodrush. Blackroot sedge often occurs on drier microsites. Brittle bladder-fern was found growing in-between boulders at one site. Table 37 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the krummholz, Klootch Family ET were mostly shallow to moderately deep with a low degree of soil development, moderate to high coarse fragments (47–73%, avg. 62%), and low clay (avg. 12%). A typical soil features an A/Bw/Cr-R horizonation. One soil was formed in deep glacial till, with a thick Bw-horizon (87 cm thick) over a sandy (91%) C-horizon (+9 cm thick). Diagnostic soil horizons include an ochric (avg. 8 cm thick) or umbric (23 cm thick) epipedon, a cambic horizon (avg. 31 cm thick), and lithic or paralithic contact (avg. 44 cm depth). Entisols lack a cambic horizon. Soils were loamy-skeletal Typic Dystrocryepts [1], Oxyaquic Dystrocryepts [1], and Lithic Cryorthents [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Typic Dystrocryepts

A—0 to 20 cm: black (10YR 2/1) very bouldery fine sandy loam, very dark gray (10YR 3/1), dry; 62% sand; 19% clay; moderate medium subangular blocky structure, and moderate medium granular structure; friable, slightly hard, slightly sticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 6% 2- to 75-mm unspecified fragments and 14% 76- to 250-mm unspecified fragments and 25% 601- to 3000-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.1; clear smooth boundary.

Bw—20 to 69 cm: dark brown (10YR 3/3) extremely bouldery sandy loam, yellowish brown (10YR 5/4), dry; 77% sand; 13% clay; weak medium subangular blocky structure parting to weak fine subangular blocky structure; very friable, slightly hard, slightly sticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 7% 251- to 600-mm unspecified fragments and 11% 2- to 75-mm unspecified fragments and 17% 76- to 250-mm unspecified fragments and 38% 601- to 3000-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; gradual wavy boundary.

Cr—69 to 73 cm: variegated, brown (10YR 5/3) and yellowish brown (10YR 5/4), dry; 94% sand; 4% clay; single grain; loose, nonsticky, nonplastic; common very fine roots; common very fine pores; 12% 251- to 600-mm unspecified fragments and 25% 76- to 250-mm unspecified fragments and 26% 601- to 3000-mm unspecified fragments and 30% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.7; abrupt wavy boundary.

R—73 cm: granodiorite bedrock.

Ecology

Three distinct morphological forms of trees are associated with the transition between subalpine forests and alpine tundra environments (Grant and Mitton 1977). The morphological forms are related to specific micro-environmental conditions associated with increasing elevation and wind exposure. The spire form is associated with trees in subalpine forests. This is the typical growth-form of a tree with a central stem, and radiating branches. The flagged growth-form features short, erect stems appearing much like a flag in a stout wind, with the only living branches on the leeward side of the tree. This growth-form is typical of the transition zone between subalpine forest and alpine tundra. Lastly, the krummholz or elfinwood growth-form features a shrub-like appearance with semi-erect to prostrate stems. The three growth-forms include a variety of intergrades, making it difficult at times to distinguish between each. The krummholz growth-form is most typical of trees in the krummholz, Klootch Family ET. The flagged growth-form may occur at lower elevation of this ET.

Krummholz is derived from the German words "krumm," meaning crooked or bent, and "holz," meaning wood. A debate exists regarding the causal factors associated with the development of the krummholz growth-form, with some arguing for a strictly genetic basis, and others for a purely environmental cause (Grant and Mitton 1977). In fact, the term "krummholz" has two different meanings in English, where it is used to refer to stunted and crooked individuals of normally upright growing trees due to desiccation from strong winds or abrasion from blowing snow and ice experienced above timberline, and in German, where it is used to refer to a crooked growth that is fixed genetically (Holtmeier 1973). Trees featuring the krummholz form reproduce most common through an asexual process termed layering. New stems arise as the layering branches closest to the ground eventually become buried in litter and sprout roots. This ET, when dominated by the "flagged" growth-form, may occur as tree islands that slowly move across the alpine tundra in the direction of the wind (see the ABLA/RIMO2, Elting Family ET for a complete review of tree islands) (Marr 1977). However, the true krummholz form of this ET usually occurs as isolated stands separated by patches of alpine meadow vegetation, which are relatively stationary on the landscape.

Management considerations

Traditional management issues important in montane and subalpine forests, including timber harvest and prescribed fire, are of little importance in these high elevation "forests" that occur almost exclusively within wilderness boundaries. Forest fire is rare at these high elevation sites; however, it can occur due to lightning strike or as large, high intensity fires invade from lower elevation forests (Bradley and others 1992). Physical disturbance due to avalanches, snow and wind abrasion, or rockslide more commonly destroy these stands and reset the successional pathway. Krummholz may be found in avalanche tracks where the low-growing form is less susceptible than the spire growth-form to damage by frequent avalanches. Although stem diameter of whitebark pine is too small (<8–13 cm) and the climate too severe for mountain pine beetle infestations, whitebark pine in these stands may be at risk of white pine blister rust, especially under future climate warming (Resler and Tomback 2008). Pedicularis and Castilleja species have recently been identified as alternate hosts of white pine blister rust (McDonald and others 2006). Please refer to the "Principal Species Description" for whitebark pine for more details on the management implications of this recent finding.

The Krummholz, Klootch Family ET has high aesthetic, watershed, and wildlife value. The snow trapped in drifts on the leeward side of this ET melts slowly throughout the summer months, providing a steady source of water for the streams and rivers down valley. These small "forest" stands provide one of the only forms of refuge for large mammals foraging in nearby alpine meadows and are home to numerous songbirds and small mammals. Moose were commonly observed browsing on willow stems in this ET.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/gooseberry currant, Elting Family ET

Floristic differences: The two types differ floristically in that the trees in the Elting Family ET feature a flagged growth-form, whereas the trees in the Klootch Family ET most often feature a krummholz growth-form. However, the flagged growth-form may occur at lower elevations in the Klootch Family ET, in which case the two Ecological Types differ in the absence of gooseberry currant in the Klootch Family ET.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs at or slightly below timberline, whereas the Klootch Family ET occurs at relatively higher elevations above timberline near the physiological limits of tree growth.

Table 36—Summary of environmental variables for the Krummholz, Klootch Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,290	3,232	3,364
Slope (%)	23	12	31
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	819	771	855
Degree days	9,359	8,877	9,997
Frost-free days	15.9	15.6	16.4
Site water balance (mm/year)	-145	-159	-130
Average annual temperature (°C)	-1.3	-1.6	-1.0
Total annual potential evapotranspiration (mm)	392	375	414
Summer radiation (KJ)	19,950	19,240	20,990
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	62	47	73
Clay (% in particle size control section)	12	9	13
pH (in particle size control section)	4.9	4.8	5.0
Available water capacity (mm/m)	27	11	46
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	0	0	0
Exposed bedrock	8	5	10
Gravel	3	1	5
Cobble	7	2	15
Stones	9	3	15
Boulders	13	5	20
Litter	8	3	15
Wood	1	0	2
Moss and lichen	16	2	25
Basal vegetation	33	10	50
Water	0	0	0

Table 37—Constancy/cover table for common plant species occurring in the Krummholz, Klootch Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ABLA	*Abies lasiocarpa*	Subalpine fir	100	5	1	10
PHEM	*Phyllodoce empetriformis*	Pink mountainheath	67	1	1	1
PIAL	*Pinus albicaulis*	Whitebark pine	100	9	1	15
SAGLV	*Salix glauca* var. *villosa*	Grayleaf willow	67	10	10	10
VASC	*Vaccinium scoparium*	Grouse whortleberry	67	3	3	3
Forbs:						
ANME2	*Antennaria media*	Rocky Mountain pussytoes	67	2	1	3
ARSC	*Artemisia scopulorum*	Alpine sagebrush	100	3	1	5
ERCO24	*Eremogone congesta*	Ballhead sandwort	67	2	1	3
ERPES3	*Erigeron peregrinus* var. *scaposus*	Subalpine fleabane	67	3	1	5
GEROT	*Geum rossii* var. *turbinatum*	Ross' avens	67	2	1	3
POBI6	*Polygonum bistortoides*	American bistort	100	3	1	5
POGR9	*Potentilla gracilis*	Slender cinquefoil	67	5	3	7
SARH2	*Saxifraga rhomboidea*	Diamondleaf saxifrage	67	1	1	1
SEST2	*Sedum stenopetalum*	Wormleaf stonecrop	100	3	1	7
SIPR	*Sibbaldia procumbens*	Arizona cinquefoil	67	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	Manyray goldenrod	67	2	1	3
Grasses:						
CAPU	*Calamagrostis purpurascens*	Purple reedgrass	67	1	1	1
FESA	*Festuca saximontana*	Rocky Mountain fescue	67	3	3	3
PHAL2	*Phleum alpinum*	Alpine timothy	67	3	1	5
POAL2	*Poa alpina*	Alpine bluegrass	67	1	1	1
POCU3	*Poa cusickii*	Cusick's bluegrass	67	6	3	10
TRSP2	*Trisetum spicatum*	Spike trisetum	100	1	1	1
Graminoids:						
CAEL3	*Carex elynoides*	Blackroot sedge	67	5	3	7
CASC10	*Carex scirpoidea*	Canadian single-spike sedge	67	3	3	3
LUSP4	*Luzula spicata*	Spike woodrush	100	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Whitebark Pine/Grouse Whortleberry, Jeru Family Ecological Type

Pinus albicaulis/Vaccinium scoparium, Jeru Family Ecological Type

PIAL/VASC, Jeru Family ET

N = 11

Distribution

The whitebark pine/grouse whortleberry, Jeru Family Ecological Type occurs in the northern and southern study areas within the granitic subalpine zone of Chapman and others (2004). This ET occurs along the upper extent of all of the major drainages in the study area, including Jakeys Fork, East Fork Torrey Creek, Dinwoody Creek, Dry Creek, Bull Lake Creek, South Fork Little Wind River, North Fork Popo Agie River, and the Middle Fork Popo Agie River.

This ET is a component of map units 327S, 310L, 311, and 311L.

Environment

Aspect: South [3], south-southeast [2], south-southwest [3], southwest [2], west-northwest [1].

Landforms and Landscape Position: Kames, lateral and ground moraines, mountain slopes. Backslopes, footslopes.

In map unit 327S, this ET occurs primarily on footslopes and backslopes of lateral moraines along the lower extent of glacial valleys. In map unit 310L, this ET occurs on kames and lateral moraines along the upper extent of glacial valleys, including the areas around South Fork Lakes, Washakie Lake, and Tayo Lake. This ET also occurs in map unit 310L in colluvial soils on mountain slopes above the lateral moraines of map unit 327S. In map unit 311L, this ET occurs at footslope positions, gentle depressions, and other areas of moderate topography where slope wash and colluvium have accumulated and site conditions have been stable long enough for deep soils to have formed.

Parent Materials: Granitic glacial till, colluvium over granitic glacial till, colluvium over residuum.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite.

In the southern portion of the study area, south of and including the Middle Fork Popo Agie drainage, bedrock is primarily granodiorite of the Louis Lake Pluton; however, pockets of gneiss occur as well. In the southern portion of the study area, north of the Middle Fork Popo Agie drainage, bedrock is porphyritic quartz monzonite. In the northern portion of the study area, bedrock tends to be migmatite and/or gneiss.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 72 to 83 cm.

Additional environment data summaries are provided in Table 38.

Potential natural vegetation

The potential natural vegetation for this ecological type is the whitebark pine/grouse whortleberry habitat type (Steele and others 1983). Lodgepole pine and Engelmann spruce are the major seral species at the lower and upper elevations, respectively. At lower elevations, lodgepole pine coexists with whitebark pine in the overstory for significant time periods. At higher elevations, lodgepole pine is less successful and gradually declines in abundance as stand age increases.

At higher elevations, Engelmann spruce is sometimes codominate with whitebark pine, especially where site conditions allow for relatively high soil moisture, such as on lower gradient slopes (≤20%). Engelmann spruce regeneration is limited at drier, steeper sites and at the highest elevation sites (> approximately 3100 m). Whitebark pine is always present and vigorously reproducing in the understory canopy layer. Subalpine fir seedlings occasionally occur; however, regeneration potential is generally limited at these south-facing sites.

Grouse whortleberry forms a thick low shrub layer. The abundance of grouse whortleberry in the PIAL/VASC, Jeru Family ET is less dependent on specific site conditions than in the PIAL/VASC, Salt Chuck Family ET. This is most likely an effect of the higher elevations and associated cooler temperatures experienced by the PIAL/VASC, Jeru Family ET in mediating the effects of aspect and slope position on micro-climatic conditions. Common juniper may also occur in limited amounts. Forbs and graminoids are generally infrequent and scattered. Heartleaf arnica, Ross' sedge, and Wheeler's or Cusick's bluegrass are the most prolific herbaceous species. Summaries of species constancy/cover and stand characteristics are provided in Tables 39 and 40, respectively.

Soils

The soils in this ET are relatively young as they are derived from Pinedale age glacial till deposited between 22,000 and 15,000 years ago (Dahms 2004b; Dahms, D.E., pers. comm.). Soils in the PIAL/VASC, Jeru Family ET were moderately deep [4] and deep [7] with a low to moderate degree of soil development, moderate to high rock fragments (37-87%, avg. 64%), and low to moderate clay (5-25%, avg. 13%). A thin (avg. 4 cm thick) litter layer occurs at the surface. A typical soil features an A/Bw/CB-C horizon. On average, moderately deep soils featured bedrock or paralithic contact at 84 cm below the soil surface. One soil featured a thick, dense layer of compacted glacial till (Cd-horizon) between 57 and 102 cm below the soil surface. Another soil featured an 8-cm thick E-horizon directly below a 2-cm thick A-horizon. Diagnostic soil horizons include an ochric epipedon (avg. 14 cm thick), and cambic horizon (avg. 50 cm thick). Particle size included sandy-skeletal [3], and loamy-skeletal [8]. Soils were Typic Eutrocryepts [2], Typic Dystrocryepts [7], and Typic Cryorthents [2].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Typic Dystrocryepts

A—3 to 10 cm: dark grayish brown (10YR 4/2) stony loam, grayish brown (10YR 5/2), dry; 42% sand; 14% clay; moderate fine subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 2% 76- to 250-mm unspecified fragments and 12% 251- to 600-mm unspecified fragments and 14% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; clear wavy boundary.

Bw—10 to 34 cm: dark yellowish brown (10YR 4/4) very stony sandy clay loam, yellowish brown (10YR 5/4), dry; 54% sand; 21% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very coarse roots and common very fine roots; common fine and common medium and common very coarse and common very fine pores; 3% 76- to 250-mm unspecified fragments and 8% 601- to 3000-mm unspecified fragments and 16% 2- to 75-mm unspecified fragments and 17% 251- to 600-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; clear wavy boundary.

2CB—34 to 59 cm: dark yellowish brown (10YR 4/4) extremely bouldery coarse sandy loam, light yellowish brown (10YR 6/4), dry; 74% sand; 13% clay; weak fine subangular blocky structure, and moderate fine granular structure; very friable, loose, slightly sticky, nonplastic; common medium roots and common coarse roots and common very fine roots; common medium and common coarse and common very fine pores; 6% 76- to 250-mm unspecified fragments and 10% 251- to 600-mm unspecified fragments and 31% 601- to 3000-mm unspecified fragments and 42% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; clear wavy boundary.

2C—59 to 104 cm: light olive brown (2.5Y 5/4) extremely bouldery loamy sand, pale yellow (2.5Y 7/4), dry; 80% sand; 9% clay; single grain; loose, nonsticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 3% 76- to 250-mm unspecified fragments and 4% 251- to 600-mm unspecified fragments and 31% 601- to 3000-mm unspecified fragments and 33% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8.

Ecology

The PIAL/VASC, Jeru Family ET represents the higher elevation, cold, moist end of the whitebark pine series. At these higher elevations, in upper subalpine and timberline forests this ET is limited to dry, south-facing slopes where whitebark pine is more competitive than subalpine fir and Engelmann spruce and forms climax stands. The subalpine fir/grouse whortleberry habitat type occurs on adjacent north-facing slopes, while the Engelmann spruce/grouse whortleberry habitat type inhabits adjacent sites with low slope gradient and high soil moisture. Whitebark pine is seral to the more shade tolerant subalpine fir and Engelmann spruce on these cooler, wetter sites. The spatial distribution of this ET is tied to the combined effect of the relationship between whitebark pine and the Clark's nutcracker and the lower shade-tolerance and higher drought-tolerance of whitebark pine compared with subalpine fir and Engelmann spruce.

Succession

A likely succession pathway for the PIAL/VASC, Jeru Family ET begins with a brief herbaceous/shrub stage (A) in which grouse whortleberry regenerates rapidly from underground rhizomes and quickly dominates the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven-aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand (C), then by a mature lodgepole pine and whitebark pine stand (D), and eventually by a climax stand of mixed lodgepole and whitebark pine (E). Regeneration of lodgepole and whitebark pine at stage (E) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for whitebark pine, which is slightly more shade tolerant than lodgepole pine. At higher elevations, lodgepole pine begins to decline in stage (D) and is a minor component of the climax stand. Low to moderate intensity fires at stages (C) through (E) will maintain the stand at each respective stage, while severe fires at stages (C) through (E) will completely reset the successional pathway.

Management considerations

This ET occurs almost exclusively within wilderness boundaries, and traditional management issues important in montane and subalpine forests, including timber harvest and prescribed fire, are of little importance. Whitebark pine forests at these higher elevations typically experience less severe droughts and colder temperatures and are at less of a risk of mountain pine beetle infestations than lower elevation whitebark pine forests. *Pedicularis* and *Castilleja* species have recently been identified as alternate hosts of white pine blister rust (McDonald and others 2006). Please refer to the "Principal Species Description" for whitebark pine for more details on the management implications of this recent finding. This ET provides important habitat for black and grizzly bears, which feed on whitebark pine cones and the berries of grouse whortleberry.

Similar ecological types

Ecological Type 1

Type: Whitebark pine/grouse whortleberry, Salt Chuck Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Salt Chuck Family ET occurs on till deposits at lower elevations (< approximately 3000 m), whereas the Jeru Family ET occurs on till deposits at higher elevations (≥ approximately 3000 m).

Ecological Type 2

Type: Whitebark pine/grouse whortleberry, Elting Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Elting Family ET occurs on moderately deep colluvial and residual soils on backslopes and shoulders, whereas the Jeru Family ET occurs on footslopes and backslopes in moderately deep and deep soils formed from glacial till.

Ecological Type 3

Type: Whitebark pine/grouse whortleberry, Sig Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Sig Family ET occurs on shallow residual soils on shoulders and summits, whereas the Jeru Family ET occurs on footslopes and backslopes in moderately deep and deep soils formed from glacial till.

Table 38—Summary of environmental variables for the PIAL/VASC, Jeru Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	3,105	2,983	3,260
Slope (%)	23	2	48
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	762	716	831
Degree days	10,970	9,373	12,340
Frost-free days	17.0	16.0	17.8
Site water balance (mm/year)	-186	-254	-129
Average annual temperature (°C)	-0.6	-1.3	0.0
Total annual potential evapotranspiration (mm)	472	420	528
Summer radiation (KJ)	20,710	19,830	20,960
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	64	37	87
Clay (% in particle size control section)	13	5	25
pH (in particle size control section)	4.9	4.8	5.1
Available water capacity (mm/m)	50	16	80
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	5
Exposed bedrock	0	0	0
Gravel	1	0	3
Cobble	4	0	10
Stones	9	2	15
Boulders	7	1	15
Litter	34	0	65
Wood	6	3	15
Moss and lichen	2	0	4
Basal vegetation	31	15	60
Water	0	0	0

Table 39—Constancy/cover table for common plant species occurring in the PIAL/VASC, Jeru Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	91	16	3	30
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	45	10	3	15
PIEN	*Picea engelmannii*	Engelmann spruce	91	6	1	10
Subdominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	82	12	3	25
PIEN	*Picea engelmannii*	Engelmann spruce	45	4	1	10
Saplings:						
PIAL	*Pinus albicaulis*	whitebark pine	82	4	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	64	1	1	3
Seedlings:						
ABLA	*Abies lasiocarpa*	subalpine fir	45	1	1	3
PIAL	*Pinus albicaulis*	whitebark pine	100	4	1	7
PIEN	*Picea engelmannii*	Engelmann spruce	82	2	1	3
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	common juniper	45	4	3	5
VASC	*Vaccinium scoparium*	grouse whortleberry	100	50	20	80
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	45	1	1	1
ARCO9	*Arnica cordifolia*	heartleaf arnica	82	4	1	10
CHAN9	*Chamerion angustifolium*	fireweed	45	1	1	1
HITRG2	*Hieracium triste* var. *gracile*	slender hawkweed	45	1	1	1
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	64	2	1	5
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	64	3	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 40—Stand characteristics for the PIAL/VASC, Jeru Family ET.

Species	Basal area		Diameter at breast height (DBH)		Trees per hectare	
	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
ABLA	2.3	—	21.6	13.0–30.0	104	32–175
PIAL	25.3	4.6–50.5	30.0	8.4–70.4	684	67–3,288
PICOL	14.2	2.3–34.4	36.6	19.3–59.0	161	7–469
PIEN	11.5	2.3–43.6	37.8	16.5–63.0	148	17–454

Species	Site tree averages		
	DBH	Height	Age
	Centimeters	*Meters*	*Years*
ABLA	13.0	7	—
PIAL	31.5	16	197
PICOL	38.1	22	244
PIEN	37.6	19	174

Whitebark Pine/Grouse Whortleberry, Salt Chuck Family Ecological Type

Pinus albicaulis/Vaccinium scoparium, Salt Chuck Family Ecological Type

PIAL/VASC, Salt Chuck Family ET

N = 7

Distribution

The whitebark pine/grouse whortleberry, Salt Chuck Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs on the upper extent of a glacial moraine that extends east from Christina Lake and Silas and Atlantic Canyons to just north-northeast of Louis Lake. It is a component of map unit 327L and 327W. This ecological type occurs in map unit 327L on the upper extent (approximately west of the Louis Lake Loop Road) of the Louis Lake moraine unit. In map unit 327W, this ecological type occurs west and southwest of Worthen Meadows reservoir and near the headwaters of Sawmill Creek.

Environment

Aspect: East-southeast [1], north [1], northeast [1], north-northeast [1], southeast [2], west-northwest [1].]

Landforms and Landscape Position: Kames; lateral, recessional, and end moraines. Summits, shoulders, backslopes.

Parent Materials: Granitic glacial till.

Bedrock: Granodiorite of the Louis Lake Pluton.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 73 cm.

Additional environment data summaries are provided in Table 41.

Potential natural vegetation

The potential natural vegetation for this ecological type is the whitebark pine/grouse whortleberry habitat type (Steele and others 1983). Lodgepole pine is the major seral species. At lower elevations, lodgepole pine coexists with whitebark pine in the overstory for significant time periods. At higher elevations, lodgepole pine is less successful and gradually declines in abundance as stand age increases. Whitebark pine is always present and vigorously reproducing in the understory canopy layer. Subalpine fir seedlings may occur as scattered individuals, and adjacent sites may fall into the subalpine fir/grouse whortleberry habitat type.

Grouse whortleberry, although always present, occurs at varying amounts depending on site conditions. At more sheltered sites, including north-facing slopes and gentle depressions, grouse whortleberry is more prolific than at more exposed sites, including south-facing slopes, shoulder positions, and gentle rises. Common juniper may also occur in limited amounts. Forbs and graminoids are generally infrequent and scattered. Heartleaf arnica and Ross' sedge are the most common and abundant herbaceous species. Summaries of species constancy/cover and stand characteristics are provided in Tables 42 and 43, respectively.

Soils

The soils in this ET are relatively young as they are derived from Pinedale age glacial till deposited between 22,000 and 15,000 years ago (Dahms 2004b; Dahms, D.E., pers. comm.). These soils have had relatively little time to develop compared to soils derived from older glacial till deposits. The soils were deep (>1 m), high (avg. 72%) in rock fragments, sandy, and minimally developed and featured very little clay illuviation. Soils in this ET typically featured an A-AB/Bw/Cb-C horizonation. One soil lacked an A-horizon, featuring instead a 12-cm thick E-horizon directly beneath pine needle litter. Another soil, occurring along the periphery of the Louis Lake Moraine unit east of Christina Lake, featured a thick Bt-horizon (75 cm thick) and 23% clay in the particle size control section. Diagnostic soil horizons include an ochric epipedon (avg. 15 cm thick), and a cambic horizon (avg. 53 cm thick). Mollic and umbric epipedons may occur occasionally. Particle size class included loamy-skeletal [4] and sandy-skeletal [2]. Soils included Humic Eutrocryepts [2], Typic Dystrocryepts [2], Typic Eutrocryepts [1], and Typic Argicryolls [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Humic Eutrocryepts

Oi1—0 to 2 cm: slightly decomposed plant material; abrupt wavy boundary.

Oi2—2 to 5 cm: slightly decomposed plant material; Horizon 2 is really organic matter in upper portion; abrupt wavy boundary.

A—5 to 25 cm: dark brown (10YR 3/3) medium gravelly sandy loam, brown (10YR 5/3), dry; 56% sand; 15% clay; weak fine granular structure, and weak medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many medium roots and common very fine roots; common fine and many medium and common very fine pores; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 16% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear irregular boundary.

Bw1—25 to 54 cm: olive brown (2.5Y 4/3) very cobbly sandy loam, light yellowish brown (2.5Y 6/3), dry; 78% sand; 11% clay; weak fine subangular blocky structure; friable, soft, slightly sticky, nonplastic; common very fine and fine roots and common medium roots; common very fine and fine and common medium pores; 24% nonflat subrounded indurated 76- to 250- mm unspecified fragments and 32% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; clear wavy boundary.

Bw2—54 to 89 cm: olive brown (2.5Y 4/3) extremely gravelly loamy sand, light gray (2.5Y 7/2), dry; 81% sand; 5% clay; weak fine subangular blocky structure, and weak medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and few medium roots and common very fine roots; common fine and common medium and common very fine pores; 10% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 18% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 37% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.5; clear wavy boundary.

C—89 to 106 cm: olive brown (2.5Y 4/3) extremely gravelly loamy sand, light yellowish brown (2.5Y 6/3), dry; 84% sand; 11% clay; massive; very friable, soft, slightly sticky, nonplastic; common very fine roots; common very fine pores; 13% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 49% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3.

Ecology

The PIAL/VASC, Salt Chuck Family ET represents forests on the middle and upper extent of glacial moraines around Louis Lake, Christina Lake, and Worthen Meadows reservoir. This ET is limited to dry, south-facing slopes where whitebark pine is more competitive than subalpine fir and Engelmann spruce and forms climax stands. The subalpine fir/grouse whortleberry habitat type occurs on adjacent north-facing slopes, while the Engelmann spruce/grouse whortleberry habitat type inhabits adjacent sites with low slope gradient and high soil moisture. Whitebark pine is seral to the more shade tolerant subalpine fir and Engelmann spruce on these cooler, mesic sites. The spatial distribution of this ET is tied to the combined effect of the relationship between whitebark pine and the Clark's nutcracker and the lower shade-tolerance and higher drought-tolerance of whitebark pine compared with subalpine fir and Engelmann spruce.

Succession

A likely succession pathway for the PIAL/VASC, Salt Chuck Family ET begins with a brief herbaceous/shrub stage (A) in which grouse whortleberry regenerates rapidly from underground rhizomes and quickly dominates the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven-aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open pole-sized lodgepole and whitebark pine stand (C), then by a mature lodgepole pine and whitebark pine stand (D), and eventually by a climax stand of mixed lodgepole and whitebark pine (E). Regeneration of lodgepole and whitebark pine at stage (E) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for whitebark pine, which is slightly more shade tolerant than lodgepole pine. At higher elevations, lodgepole pine begins to decline in stage (D) and is a minor component of the climax stand. Low to moderate intensity fires at stages (C) through (E) will maintain the stand at each respective stage, while severe fires at stages (C) through (E) will completely reset the successional pathway.

Management considerations

The most important management consideration in these warm, lower elevation whitebark pine forests is risk of mountain pine beetle infestations. These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics in whitebark pine forests may want to consider monitoring these lower elevation mixed lodgepole and whitebark pine stands for signs of beetle activity. *Pedicularis* and *Castilleja* species have recently been identified as alternate hosts of white pine blister rust (McDonald and others 2006). Please refer to the "Principal Species Description" for whitebark pine for more details on the management implications of this recent finding.

This ET occurs near the interface of wilderness and non-wilderness lands, and traditional management issues, including timber harvest and prescribed fire, may be more pertinent than in similar Ecological Types that occur exclusively within wilderness boundaries (e.g., PIAL/VASC, Jeru Family ET). Light ground fires and low to moderate severity burns help maintain whitebark pine forests by killing seedlings of competing species. Stand replacing burns can be used to open up large areas of bare mineral soil where whitebark pine seeds may be readily planted by Clark's nutcrackers. However, if stand replacing burns are used as a management tool in whitebark pine forests, careful consideration should be given to the availability of adjacent whitebark pine to act as seed trees.

Although this ecological type is not suited for commercial timber harvest, a variety of silvicultural treatments may be used to promote whitebark pine. Depending on the degree of wind exposure at a site, the following treatments are recommended (in order from most to least exposed): clear-cutting, seed tree, shelterwood, and uneven-aged, group selection, and single tree (Eggers 1990). If clear-cutting is chosen as the appropriate silvicultural treatment, careful consideration should be given to the size of the clear-cut relative to the availability of adjacent whitebark pine to act as seed trees. This ET provides important habitat for black and grizzly bears, which feed on whitebark pine cones and the berries of grouse whortleberry.

Similar ecological types

Ecological Type 1

Type: Whitebark pine/grouse whortleberry, Jeru Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Salt Chuck Family ET occurs on till deposits at lower elevations (< approximately 3000 m), whereas the Jeru Family ET occurs on till deposits at higher elevations (≥ approximately 3000 m).

Table 41—Summary of environmental variables for the PIAL/VASC, Salt Chuck Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,829	2,688	2,975
Slope (%)	20	10	35
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	679	632	732
Degree days	14,220	12,590	15,780
Frost-free days	18.6	17.8	19.3
Site water balance (mm/year)	-243	-281	-207
Average annual temperature (°C)	0.8	0.0	1.5
Total annual potential evapotranspiration (mm)	546	498	606
Summer radiation (KJ)	20,300	19,600	20,980
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	72	61	87
Clay (% in particle size control section)	14	7	23
pH (in particle size control section)	5.1	4.8	5.3
Available water capacity (mm/m)	40	24	51
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	0	0	0
Exposed bedrock	0	0	0
Gravel	2	0	5
Cobble	5	1	15
Stones	7	3	10
Boulders	12	3	25
Litter	41	30	50
Wood	8	2	15
Moss and lichen	2	1	4
Basal vegetation	23	20	25
Water	0	0	0

Table 42—Constancy/cover table for common plant species occurring in the PIAL/VASC, Salt Chuck Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	43	9	3	15
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	10	3	20
Subdominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	57	6	5	10
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	86	11	5	25
Saplings:						
PIAL	*Pinus albicaulis*	whitebark pine	86	3	1	5
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	86	3	1	10
Seedlings:						
ABLA	*Abies lasiocarpa*	subalpine fir	43	2	1	3
PIAL	*Pinus albicaulis*	whitebark pine	100	3	1	5
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	86	2	1	5
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	common juniper	43	3	1	5
SHCA	*Shepherdia canadensis*	russet buffaloberry	43	7	3	15
VASC	*Vaccinium scoparium*	grouse whortleberry	100	34	3	65
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	2	1	5
CHAN9	*Chamerion angustifolium*	fireweed	43	1	1	1
LUAR3	*Lupinus argenteus*	silvery lupine	43	2	1	3
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	43	1	1	1
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	43	1	1	1
TRSP2	*Trisetum spicatum*	spike trisetum	43	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	57	2	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 43—Stand characteristics for the PIAL/VASC, Salt Chuck Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------*Centimeters*-------			
ABLA	2.3	—	30.0	20.1–39.9	44	17–72
PIAL	16.0	2.3–32.1	24.9	13.5–41.9	422	72–823
PICOL	25.3	6.9–60.0	22.6	10.2–43.7	978	267–3,305
PIEN	2.3	—	27.7	—	37	—

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	30.0	24	154
PIAL	23.9	16	192
PICOL	26.4	19	164
PIEN	27.7	20	110

Whitebark Pine/Ross' Sedge, Frisco Family Ecological Type

Pinus albicaulis/Carex rossii, Frisco Family Ecological Type

PIAL/CARO5, Frisco Family ET

N = 4

Distribution

The whitebark pine/Ross' sedge, Frisco Family Ecological Type occurs along the eastern slope of the southern WRR within the granitic subalpine zone ecoregion of Chapman and others (2004). The ecological type occurs near Dickinson Park in the northeast corner of the southern study area. It is a component of map unit 310L.

Environment

Aspect: East [1], northeast [1], south [1], south-southwest [1].

Landforms and Landscape Position: Mountain slopes. Shoulders and backslopes.

Parent Materials: Quartz monzonite colluvium over quartz monzonite residuum.

Bedrock: Precambrian quartz monzonite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 68 to 72 cm.

Additional environment data summaries are provided in Table 44.

Potential natural vegetation

The potential natural vegetation for this ecological type is the whitebark pine/Ross' sedge habitat type-lodgepole pine phase (Steele and others 1983). In younger stands, lodgepole pine dominates the overstory. Whitebark pine shares dominance in the overstory with lodgepole pine in older stands. Whitebark pine is always present and vigorously regenerating in the understory.

The shrub layer is extremely species poor and sometimes completely lacking. Kinnikinnick and common juniper are the most likely shrub species to occur in this ET. Similar to the shrub layer, the herbaceous layer is sparse and the ground surface is characterized by high coverage of pine needle litter, bare ground, and boulders. There is typically not one dominant species; however, Ross' sedge and Wheeler's bluegrass are the most common herbaceous species. Heartleaf arnica and manyray goldenrod may also occur. Summaries of species constancy/cover and stand characteristics are provided in Tables 45 and 46, respectively.

Soils

Soils in the PIAL/CARO5, Frisco Family ET were moderately deep and deep, sandy, and characterized by a low to moderate degree of soil development, high coarse fragments (avg. 72%), and low to moderately high clay (3-21%, avg. 11%). A thin (avg. 2 cm thick) litter layer occurs at the surface. A typical soil features an A/Bt-Bw/C-Cr horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 12 cm thick), and an argillic horizon (avg. 70 cm thick). Inceptisols featured a cambic horizon (avg. 21 cm thick) in place of an argillic horizon. One soil featured a 17-cm thick E-horizon directly below the A-horizon, while another soil was characterized by dark Mollic colors in the upper 20 cm of the soil. Soils were loamy-skeletal Eutric Haplocryalfs [1] and Mollic Haplocryalfs [1], and sandy-skeletal Typic Eutrocryepts [2].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Eutric Haplocryalfs

Oi—0 to 1 cm: slightly decomposed plant material; abrupt wavy boundary.

A—1 to 10 cm: very dark grayish brown (10YR 3/2) fine gravelly coarse sandy loam, grayish brown (10YR 5/2), dry; 72% sand; 11% clay; weak fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 2% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 31% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6; clear wavy boundary.

Bt1—10 to 34 cm: brown (10YR 4/3) very gravelly coarse sandy loam, pale brown (10YR 6/3), dry; 75% sand; 15% clay; moderate medium subangular blocky structure; friable, soft, slightly sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots; common very fine and fine and common medium and common coarse pores; 1% patchy faint clay films on all faces of peds and 2% patchy faint clay films on surfaces along root channels; 4% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 15% nonflat subrounded indurated 600- to 3000-mm unspecified fragments and 36% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; clear wavy boundary.

Bt2—34 to 75 cm: dark yellowish brown (10YR 4/4) extremely bouldery coarse sandy loam, light yellowish brown (10YR 6/4), dry; 80% sand; 17% clay; weak coarse subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 12% patchy distinct clay films between sand grains; 6% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 40% nonflat subrounded indurated 600- to 3000-mm unspecified fragments and 42% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; clear wavy boundary.

2CBt—75 to 105 cm: yellowish brown (10YR 5/4) extremely bouldery coarse sandy loam, very pale brown (10YR 7/4), dry; 79% sand; 19% clay; massive; friable, slightly hard, slightly sticky, slightly plastic; common very fine and fine roots and few medium roots; common fine and common medium and common very fine pores; 15% patchy faint clay films on all faces of peds; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 36% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 46% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3.

Ecology

The PIAL/CARO5, Frisco Family ET represents the lower elevation, warm, dry end of the whitebark pine series in map unit 310L. Whitebark and lodgepole pine are the only species capable of inhabiting these rocky, sandy, and droughty soils. Whitebark pine is a bird-dispersed species sharing a mutualistic relationship with the Clark's nutcracker. Throughout late summer and fall, the Clark's nutcracker caches pine seeds for use during the winter months. The Clark's nutcracker prefers to cache seeds in areas of low snow accumulation where snows melt earlier in the winter, including south-facing sites and windward slopes. The spatial distribution of this ET is strongly linked to the relationship between whitebark pine and the Clark's nutcracker. The thick litter layer and unproductive, acidic soils result in a highly depauperate understory where only a few hardy species can survive.

Succession

A likely succession pathway for the PIAL/CARO5, Frisco Family ET begins with a brief herbaceous stage (A) in which Ross' sedge regenerates rapidly from underground rhizomes and quickly dominates the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven-aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand (C), then by a mature lodgepole pine and whitebark pine stand (D), and eventually by a climax stand of mixed lodgepole and whitebark pine (E). Regeneration of lodgepole and whitebark pine at stage (E) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for whitebark pine, which is slightly more shade tolerant than lodgepole pine. Low to moderate intensity fires at stages (C) through (E) will maintain the stand at each respective stage, while severe fires at stages (C) through (E) will completely reset the successional pathway.

Management considerations

The most important management consideration in these warm, lower elevation whitebark pine forests is risk of mountain pine beetle infestations. These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics in whitebark pine forests may want to consider monitoring these lower elevation mixed lodgepole and whitebark pine stands for signs of beetle activity. Mountain pine beetles are favored by mild winters and warm, droughty summers—climatic factors responsible for epidemics (Howard 2002). Temperatures at low and mid-elevations have historically been most favorable for mountain pine beetle broods, and whitebark pine forests within this elevation range are at higher risk of attack. Mountain pine beetle epidemics often begin in lower elevation lodgepole pine stands and move from there into upper elevation forests (Eggers 1990). *Pedicularis* and *Castilleja* species have recently been identified as alternate hosts of white pine blister rust (McDonald and others 2006). Please refer to the "Principal Species Description" for whitebark pine for more details on the management implications of this recent finding.

This ET is not suited for timber harvest due to the low productivity and rocky soil surface. Also, vast areas of this ET occur along roads frequented by recreationists, and the large trees and open understory typical of these stands have high aesthetic value. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control of mountain pine beetles in lodgepole pine stands.

Whitebark pine seeds are an integral part of the diet of black and grizzly bears, providing an important source of calories for bears preparing for hibernation (Howard 2002). Cone scat originating from black and grizzly bears gorging themselves on whitebark pine cones was commonly found in this ET. During the herbaceous stage, directly following severe fire, this ET may provide moderate amounts of forage. However, forage production drops dramatically as stand age increases, with climax stands having little to no forage production.

Similar ecological types

Ecological Type 1

Type: Whitebark pine/Ross' sedge, Como Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Como Family ET occurs near Louis Lake and is characterized by Inceptisols and Entisols, whereas the Frisco Family ET occurs near Dickinson Park and is characterized by Alfisols and Inceptisols.

Table 44—Summary of environmental variables for the PIAL/CARO5, Frisco Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,916	2,873	2,987
Slope (%)	30	25	34
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	696	677	719
Degree days	12,710	12,140	13,140
Frost-free days	17.9	17.6	18.1
Site water balance (mm/year)	-232	-252	-193
Average annual temperature (°C)	0.3	0.1	0.5
Total annual potential evapotranspiration (mm)	503	453	537
Summer radiation (KJ)	20,100	18,960	20,910
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	72	67	77
Clay (% in particle size control section)	11	3	21
pH (in particle size control section)	5.4	5.3	5.4
Available water capacity (mm/m)	29	24	39
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	1	5
Exposed bedrock	3	0	5
Gravel	8	0	20
Cobble	4	2	5
Stones	9	5	10
Boulders	14	5	20
Litter	42	25	56
Wood	9	5	15
Moss and lichen	2	2	2
Basal vegetation	10	10	10
Water	0	0	0

Table 45—Constancy/cover table for common plant species occurring in the PIAL/CARO5, Frisco Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	75	10	5	15
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	10	10	10
Subdominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	100	5	3	10
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	8	5	10
Saplings:						
PIAL	*Pinus albicaulis*	whitebark pine	100	7	1	15
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	2	1	3
Seedlings:						
ABLA	*Abies lasiocarpa*	subalpine fir	50	1	1	1
PIAL	*Pinus albicaulis*	whitebark pine	100	4	3	5
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	2	1	3
Shrubs:						
ARUV	*Arctostaphylos uva-ursi*	kinnikinnick	50	2	1	3
JUCOD	*Juniperus communis* var. *depressa*	common juniper	50	1	1	1
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	50	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	50	1	1	1
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	100	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 46—Stand characteristics for the PIAL/CARO5, Frisco Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---*m*^{2}*/ha*---		-------*Centimeters*-------			
PIAL	12.6	4.6–16.1	25.7	13.0–46.7	408	47–902
PICOL	18.4	6.9–36.7	26.0	15.5–37.3	420	72–1,047
PIEN	4.6	—	23.4	19.8–26.7	116	—

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PIAL	28.4	13	206
PICOL	30.0	16	140
PIEN	19.8	13	113

Whitebark Pine/Ross' Sedge, Como Family Ecological Type

Pinus albicaulis/Carex rossii, Como Family Ecological Type

PIAL/CARO5, Como Family ET

N = 9

Distribution

The whitebark pine/Ross' sedge, Como Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs from Blue Ridge and the headwaters of Sawmill Creek in the north, to Willow Creek in the south, and east toward Rock Creek Reservoir. It is a component of map units 309L and 309A. To the south and east of Louis Lake, this ET occurs primarily on backslopes and shoulders of a network of diabasic gabbro dikes that have intruded into the Louis Lake Pluton (Bayley and others 1973). To the north of Louis Lake, this ET occurs on backslopes, shoulders, and summits of low- to moderate-gradient mountain slopes as the forest component of park-forest vegetation.

Environment

Aspect: East-northeast [1], northeast [1], south [2], south-southeast [2], west [1], west-northwest [2].

Landforms and Landscape Position: Diabasic gabbro dikes and mountain slopes. Summits, shoulders, and backslopes.

Parent Materials: Granodiorite residuum.

Bedrock: Granodiorite of the Louis Lake Pluton.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 76 cm.

Additional environment data summaries are provided in Table 47.

Potential natural vegetation

The potential natural vegetation of this ET is the whitebark pine/Ross' sedge habitat type (Steele and others 1983). The lodgepole pine phase was most commonly associated with the ET. Whitebark pine is present in all canopy layers with vigorous regeneration in the understory. Lodgepole pine is nearly always present in the upper canopy layers, while seedlings of lodgepole pine are always present at low abundance in the understory. Limber pine may sometimes co-occur with whitebark pine, especially at the lower elevation range of this ET.

The shrub layer is sometimes completely lacking in this ET. When a shrub layer does exist, it is typically sparse. Common juniper and mountain big sagebrush are the most common shrub species associated with the ET. Ross' sedge and Wheeler's bluegrass are always present in the herbaceous layer. Idaho fescue and sulphur-flower buckwheat are indicative of the Idaho fescue grasslands that typically co-occur as a mosaic with this ET. Summaries of species constancy/cover and stand characteristics are provided in Tables 48 and 49, respectively.

Soils

Soils in the PIAL/CARO5, Como Family ET are mostly shallow to moderately deep with a low degree of soil development, moderately high coarse fragments (avg. 56%), and moderately low clay (avg. 14%). A thin (avg. 2 cm thick) litter layer occurs at the surface. A typical soil features an A/Bw/CB-C/Cr-R horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 13 cm thick), a cambic horizon (avg. 24 cm thick), and paralithic-lithic contact (avg. 48 cm depth). One soil featured a thick argillic horizon (58+ cm thick) in place of a cambic horizon. Entisols lacked both cambic and argillic horizons. Particle size class included loamy-skeletal [5], sandy-skeletal [2], and coarse-loamy [2]. The soils were mostly Entisols and Inceptisols, including Typic Eutrocryepts [4], Typic Dystrocryepts [1], Typic Cryorthents [3], and Typic Haplocryalfs [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed, Typic Eutrocryepts

Oi—0 to 3 cm: slightly decomposed plant material; abrupt wavy boundary.

A—3 to 7 cm: dark brown (10YR 3/3) very gravelly sandy loam, brown (10YR 5/3), dry; 70% sand; 11% clay; weak fine subangular blocky structure, and weak very fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots; common fine and common medium pores; 39% 2- to 5-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 5.0; abrupt wavy boundary.

Bw—7 to 26 cm: dark yellowish brown (10YR 4/6) very gravelly sandy loam, very pale brown (10YR 7/3), dry; 68% sand; 12% clay; weak medium subangular blocky structure, and weak fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots; common fine and common medium and common coarse pores; 58% 2- to75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; clear smooth boundary.

C—26 to 64 cm: variegated very gravelly coarse sand; 95% sand; 3% clay; single grain; loose, nonsticky, nonplastic; few fine roots and few medium roots; few fine and few medium pores; 14% 601- to 3000-mm unspecified fragments and 21% 76- to 250-mm unspecified fragments and 49% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; gradual wavy boundary.

R—64 cm: granodiorite bedrock.

Ecology

The PIAL/CARO5, Como Family ET represents the lower elevation, warm, dry end of the whitebark pine series. At the lowest elevations (<2850 m), this ET is limited to north-facing slopes, while at upper elevation, this ET is found primarily on south-facing slopes. Whitebark and lodgepole pine are the only species capable of inhabiting these shallow to moderately deep, sandy, droughty residual soils. The thick litter layer and unproductive, acidic soils result in a highly depauperate understory where only a few hardy species can survive.

Park-forest vegetation refers to a mixture of non-forested and subalpine forest vegetation that occurs in a mosaic across mountainous landscapes. Park-forest vegetation is a common vegetation type across the mountains of Wyoming and southwestern Montana (Patten 1963; Despain 1973; Doering and Reider 1992; Whitlock 1993; Lynch 1998). Parks are sometimes related to environmental conditions not conducive to conifer regeneration, including poorly drained soils in valley bottoms; exposed ridges; and hot, dry, south-facing slopes (Lynch 1998). However, parks also occur on sites with similar environmental conditions to those of surrounding conifer forests, and a variety of ideas and hypotheses have been developed to explain the persistence of parks on these sites. Lynch (1998) tested three hypotheses for the persistence of park vegetation in the northwestern WRR, including the permanent site, remnant, and replacement hypotheses. In the permanent site hypothesis, parks are considered to be stable communities related to specific types of soils or topography. In the remnant hypothesis, parks are considered to be remnants of a vegetation type more common under historical climatic conditions. Lastly, the replacement hypothesis suggests that parks are the result of permanent changes in vegetation composition from forest to park following forest fire and/or climate change. Lynch (1998) concluded that the replacement hypothesis best explained the persistence of park vegetation in the northwestern WRR and provided the following explanation. A disturbance event (forest fire or windthrow) that resulted in the removal of forest cover occurred ~3500 to 2500 years BP and corresponded with a cooling trend that favored park vegetation over the regeneration of pioneer tree species. A positive feedback between park vegetation and microclimate would maintain the park vegetation by exposing tree seedlings to increased temperatures, solar radiation, and water stress. Whitlock (1993) provided a similar explanation for the development of park vegetation in Yellowstone National Park, suggesting that increased fire frequency and changing climatic conditions gave rise to increased bark beetle infestations, thus favoring park vegetation over forest. Once parks have become established, frequent, low intensity fires would kill tree seedlings invading the parks, while leaving adult conifers in adjacent forest patches unharmed, thus maintaining the park-forest mosaic.

Succession

A likely succession pathway for the PIAL/CARO5, Como Family ET begins with a brief herbaceous stage (A) in which Ross' sedge regenerates rapidly from underground rhizomes and quickly dominates the site. Immediately following the fire, during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven-aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand (C), then by a mature lodgepole pine and whitebark pine stand (D), and eventually by a climax stand of mixed lodgepole and whitebark pine (E). Regeneration of lodgepole and whitebark pine at stage (E) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for whitebark pine, which is slightly more shade tolerant than lodgepole pine. Low to moderate intensity fires at stages (C) through (E) will maintain the stand at each respective stage, while severe fires at stages (C) through (E) will completely reset the successional pathway.

Management considerations

The most important management consideration in these warm, lower elevation whitebark pine forests is risk of mountain pine beetle infestations. These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics in whitebark pine forests may want to consider monitoring these lower elevation mixed lodgepole and whitebark pine stands for signs of beetle activity. Mountain pine beetles are favored by mild winters and warm, droughty summers—climatic factors responsible for epidemics (Howard 2002). Temperatures at low and mid-elevations have historically been most favorable for mountain pine beetle broods, and whitebark pine forests within this elevation range are at higher risk of attack. *Pedicularis* and *Castilleja* species have recently been identified as alternate hosts of white pine blister rust (McDonald and others 2006). Please refer to the "Principal Species Description" for whitebark pine for more details on the management implications of this recent finding.

This ET is not suited for timber harvest as it is not highly productive. These stands have high watershed value by retaining winter snowfall in the form of large drifts on the sheltered, leeward side of the stands. Also, vast areas of this ET occur along roads frequented by recreationists, and the large trees and open understory typical of these stands have high aesthetic value. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control of mountain pine beetles in lodgepole pine stands.

Whitebark pine seeds are an integral part of the diet of black and grizzly bears, providing an important source of calories for bears preparing for hibernation (Howard 2002). Cone scat originating from black and grizzly bears gorging themselves on whitebark pine cones was commonly found in this ET. During the herbaceous stage, directly following severe fire, this ET may provide moderate amounts of forage. However, forage production drops dramatically as stand age increases, with climax stands having little to no forage production. These forests provide important hiding and thermal cover for wild and domestic ungulates foraging in adjacent non-forest patches, including FEID-ELSP3-ACNE9, Elwood Family ET in map unit 309A, and ARTRV2/FEID, Ledgefork Family ET and ARTRR4/FEID, Ledgefork Family ET in map unit 309L.

Similar ecological types

Ecological Type 1

Type: Whitebark pine/Ross' sedge, Frisco Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Como Family ET occurs near Louis Lake and is characterized by Inceptisols and Entisols, whereas the Frisco Family ET occurs near Dickinson Park and is characterized by Alfisols and Inceptisols.

Table 47—Summary of environmental variables for the PIAL/CARO5, Como Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,838	2,630	3,078
Slope (%)	17	10	28
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	692	627	764
Degree days	13,970	11,660	16,000
Frost-free days	18.5	17.3	19.5
Site water balance (mm/year)	-272	-326	-214
Average annual temperature (°C)	0.8	-0.1	1.6
Total annual potential evapotranspiration (mm)	554	520	615
Summer radiation (KJ)	20,630	19,750	21,640
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	56	30	83
Clay (% in particle size control section)	14	3	28
pH (in particle size control section)	5.0	4.8	5.4
Available water capacity (mm/m)	34	19	76
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	7	2	15
Exposed bedrock	4	0	10
Gravel	6	1	10
Cobble	6	0	15
Stones	6	0	20
Boulders	8	0	20
Litter	31	20	45
Wood	10	3	25
Moss and lichen	1	0	2
Basal vegetation	22	10	40
Water	0	0	0

Table 48—Constancy/cover table for common plant species occurring in the PIAL/CARO5, Como Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	57	11	5	20
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	71	17	5	30
Subdominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	57	10	5	15
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	71	11	5	15
Saplings:						
PIAL	*Pinus albicaulis*	whitebark pine	100	6	3	10
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	2	1	3
Seedlings:						
PIAL	*Pinus albicaulis*	whitebark pine	100	3	1	7
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	1	1	3
Forbs:						
ANRO2	*Antennaria rosea*	rosy pussy-toes	57	2	1	3
ARCO9	*Arnica cordifolia*	heartleaf arnica	57	2	1	4
ERCO24	*Eremogone congesta*	ballhead sandwort	57	2	1	3
LUAR3	*Lupinus argenteus*	silvery lupine	57	3	1	5
Grasses:						
FEID	*Festuca idahoensis*	Idaho fescue	57	2	1	5
PIMI7	*Piptatherum micranthum*	littleseed ricegrass	43	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	86	4	3	5
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	100	3	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 49—Stand characteristics for the PIAL/CARO5, Como Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---*m*^{2}*/ha*---		-------*Centimeters*-------			
ABLA	6.9	2.3–13.8	23.9	10.9–47.8	232	74–553
PICOL	13.8	2.3–23.0	27.4	12.2–45.5	351	37–1,215
PIFL2	2.3	—	40.6	—	17	—

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	22.6	10	138
PICOL	28.7	15	107
PIFL2	40.6	12	80

Miscellaneous Whitebark Pine Types

Whitebark Pine/Grouse Whortleberry, Sig Family Ecological Type

Pinus albicaulis/Vaccinium scoparium, Sig Family Ecology Type

PIAL/VASC, Sig Family ET

N = 1

The whitebark pine/grouse whortleberry, Sig Family Ecological Type occurs throughout the WRR within the granitic subalpine zone of Chapman and others (2004). This ET occurs on shoulders and summits of glacially scoured mountains dominated by rock outcrop. It is a component of map unit 311 and 311L. Parent materials include granodiorite, quartz monozonite, or migmatite and gneiss residuum. Soils were shallow to bedrock, sandy, and low in rock fragments. Soils were loamy-skeletal, Lithic Dystrocryepts.

Potential natural vegetation of this ET is the whitebark pine/grouse whortleberry habitat type (Steele and others 1983). Whitebark pine dominates all canopy layers, forming an open-canopy forest. Grouse whortleberry creates a moderately dense low shrub layer and may sometimes only occur in scattered patches. Pine needle litter (55%), boulders (10%), and rock outcrop (5%) make up the majority of the ground cover with a scant cover of forbs and graminoids, including alpine lewisia, umber pussy-toes, heartleaf arnica, ballhead sandwort, spiny milkvetch, Ross' sedge, and Wheeler's bluegrass

Whitebark pine forests at these higher elevations typically experience less severe droughts and colder temperatures and are at less of a risk of mountain pine beetle infestations than lower elevation whitebark pine forests. This ET provides important habitat for black and grizzly bears, which feed on whitebark pine cones and the berries of grouse whortleberry.

The PIAL/VASC, Sig Family ET is very similar in vegetation composition to the PIAL/VASC, Jeru Family and PIAL/VASC, Elting Family Ecological Types. The Sig Family ET differs from the Jeru and Elting Family Ecological Types in that it occurs on shallow residual soils on shoulders and summits. The Jeru Family ET occurs on footslopes and backslopes in moderately deep and deep soils formed from glacial till, while the Elting Family ET occurs on moderately deep colluvial and residual soils on backslopes and shoulders.

Whitebark Pine/Grouse Whortleberry, Elting Family Ecological Type

Pinus albicaulis/Vaccinium scoparium, Elting Family Ecological Type

PIAL/VASC, Elting Family ET

N = 1

The whitebark pine/grouse whortleberry, Elting Family Ecological Type occurs within the granitic subalpine zone of Chapman and others (2004). This ET occurs from Bomber Lake in the upper Dinwoody Creek drainage south to the Middle Fork of the Popo Agie drainage. It is a component of map unit 311L. This ET occurs on low to moderate gradient (5 to 25%) backslopes and shoulders on granitic rock outcrop. The ET was observed at elevations ranging between 2900 and 3200 m. This ET falls within the 65 to 80 cm range of annual precipitation. Parent materials are granodiorite, porphoritic quartz monzonite, migmatite, or gneiss colluvium over residuum. Soils were generally moderately deep, sandy skeletal Typic Dystrocryepts.

The potential natural vegetation for this ecological type is the whitebark pine/grouse whortleberry habitat type (Steele and others 1983). Lodgepole pine and Engelmann spruce are the major seral species at the lower and upper elevations, respectively. Whitebark pine is always present and vigorously reproducing in the understory canopy layer. Subalpine fir seedlings occasionally occur; however, regeneration potential is generally limited at these south-facing sites. Grouse whortleberry forms a thick low shrub layer. Common juniper may also occur in limited amounts. Forbs and graminoids are generally infrequent and scattered. Heartleaf arnica, Ross' sedge, and Wheeler's or Cusick's bluegrass are the most prolific herbaceous species.

The PIAL/VASC, Elting Family ET is very similar floristically to the PIAL/VASC, Jeru Family and PIAL/VASC, Sig Family ET. The Elting Family ET differs from the Jeru Family ET in that the former is characterized by moderately deep, sandy-skeletal Typic Dystrocryepts, while the latter is characterized by deep, loamy-skeletal Typic Dystrocryepts. The Elting Family ET differs from the Sig Family ET in that the former is characterized by moderately deep sandy-skeletal, Typic Dystocryepts, while the latter is characterized by loamy-skeletal, Lithic Dystrocryepts.

Whitebark Pine Series, Marosa Family Ecological Type

Pinus albicaulis Series, Marosa Family Ecological Type

PIAL, Marosa Family ET

N = 2

The whitebark pine series, Marosa Family Ecological Type occurs within the dry mid-elevation sedimentary mountains of Chapman and others (2004). This ET occurs at upper elevations (avg. 2,772 m) on shoulder and summit positions on the Flathead Formation. The soils in this ET are moderately deep and deep, moderately high in clay (avg. 19%), and rocky (avg. 66%). This ET is similar environmentally to the ABLA/VASC, Marosa Family ET but occurs on more exposed slope positions and in rockier soils.

The potential natural vegetation of this ecological type includes the whitebark pine/grouse whortleberry habitat type and the whitebark pine/common juniper habitat type. In the whitebark pine/grouse whortleberry habitat type, whitebark pine dominates all canopy layers, and is commonly joined in the overstory by lodgepole pine. Grouse whortleberry often forms a dense low shrub layer and may be joined by Oregon grape, common juniper, pipsissewa, and russet buffaloberry. The herbaceous layer is generally diffuse and may include heartleaf arnica, fireweed, white vein pyrola and sidebells wintergreen, lanceleaf springbeauty, and Ross' sedge.

In the whitebark pine/common juniper habitat type, whitebark pine co-dominates with seral lodgepole pine. Other common seral species include Douglas-fir and quaking aspen. A rich shrub canopy, including Rocky Mountain maple, russet buffaloberry, twinberry honeysuckle, and western serviceberry, overtops a sparse herbaceous layer, of which sidebells wintergreen and pipsissewa are the most common species.

Whitebark pine on the Flathead Formation occurs on exposed shoulder positions at the highest elevations (≥3,050 m) and on exposed slope positions subject to cold-air drainage at lower elevations. Significant fire-free periods must occur for whitebark pine to attain climax at these sites. This ET is not suited for timber harvest. Climax stands of whitebark pine on the sedimentary formations along the eastern flank of the WRR are unique and require specific environmental conditions to become established and many centuries without disturbance to attain maturity. Also, accessibility of logging equipment is low due to the rocky terrain associated with shoulder positions on Flathead Sandstone. The cones of whitebark pine provide a nutritious and protein-rich food source for black and grizzly bears.

Douglas-Fir Series

Principal Species Descriptions

Rocky Mountain Douglas-Fir

Pseudotsuga menziesii (Mirbel) Franco var. *glauca* (Beissn.) Franco

Douglas-fir is one of the most important coniferous tree species in North America, both ecologically and economically (Hermann and Lavender 1990). Two varieties of Douglas-fir are widely recognized: *P. menziesii* (Mirb.) Franco var. *menziesii*, commonly called coast Douglas-fir, and *P. menziesii* (Mirbel) Franco var. *glauca* (Beissn.) Franco, commonly called Rocky Mountain Douglas-fir. The native range of Rocky Mountain Douglas-fir is quite extensive, spanning some 4,500 km from its northern extent in central British Columbia, south to the mountains of central Mexico. The native range of the coast Douglas-fir is more limited, ranging some 2,200 km along the Pacific Coast from coastal British Columbia to northern and parts of central California.

Rocky Mountain Douglas-fir is tolerant of a broad range of climatic conditions (Hermann and Lavender 1990). Climatic conditions for the Rocky Mountain Douglas-fir zone include average July temperatures between 14 to 20 °C in the northern Rockies and 7 to 21 °C in the central and southern Rockies.Average January temperature between -7 to -3 °C are typical in the northern Rockies and -9 to 2 °C in the central and southern Rockies.Average annual precipitation varies between 560–1,020 mm in the northern Rockies to 360–760 mm in the central and southern Rockies. The central and southern Rocky Mountains experience a continental climate with long cold winters and hot, dry summers. Much of the precipitation arrives all at once as snow and rain in the late winter and spring months. The uneven distribution of precipitation in the central and southern Rocky Mountains combined with hot, dry summers results in an extended drought in late summer and early fall. Topography, including elevation, slope, and slope aspect, as it influences climatic factors responsible for regulating soil moisture, is very important in the spatial distribution of Rocky Mountain Douglas-fir in the central and southern Rocky Mountains, especially at the lower elevation extent (1,800–2,800 m). At lower elevations in the central and southern Rocky Mountains, contiguous stands of Rocky Mountain Douglas-fir are generally limited to cooler, more moist north-facing slopes (Hermann and Lavender 1990). The upper elevation extent of Rocky Mountain Douglas-fir in the southern and central Rocky Mountains is approximately 3,200 and 2,900 m, respectively.

Climate in the northern Rocky Mountains has a significant maritime influence, a climatic regime resulting in higher, more evenly distributed levels of precipitation and more moderate temperature fluctuations than in the central and southern Rocky Mountains. The spatial distribution of Rocky Mountain Douglas-fir at its most northerly extent, where precipitation is abundant and evenly distributed, is less limited by soil moisture and strongly limited by temperature (Hermann and Lavender 1990). In the northern part of its range, contiguous stands are generally limited to warmer, south-facing slopes, and the upper elevation extent of Rocky Mountain Douglas-fir (~760–1,500 m) reflects the inverse relationship between temperature and latitude at any given elevation, i.e., as latitude increases lower elevations experience colder temperatures.

Rocky Mountain Douglas-fir is most productive on deep, well-drained soils with a pH range from 5 to 6 (Hermann and Lavender 1990). Forests of Rocky Mountain Douglas-fir occur on a wide range of geologic substrates, including limestone, dolomite, sandstone, quartzite, siltstone, basalt, deep loess with volcanic ash, granite, tuff, rhyolite, schist, breccia, andesite, alluvium, and glacial till (Pfister and others 1977; Youngblood and Mauk 1985; Johnson and Simon 1987; Svalberg and others 1997; Johnston and others 2001). Steele and others (1983) described Rocky Mountain Douglas-fir forests as highly dependent on substrate in the central Rocky Mountains of eastern Idaho and western Wyoming. Rocky Mountain Douglas-fir forests in this region typically occur on soils derived from limestone and basic extrusive volcanics, particularly andesite and basalt. Douglas-fir is intolerant of prolonged soil saturation.

In the central and southern Rocky Mountains, pollination of Rocky Mountain Douglas-fir cones occurs between mid-May to mid-June (Hermann and Lavender 1990). Hard frosts or depredation of the cones by insects during this time period will result in the destruction of the cones and seeds before maturation. In the central and southern Rocky Mountains, the Douglas-fir cone moth (*Barbara colfaxiana*) is the most common cone pest; however, western spruce budworm will also attack cones and seeds (Hagle and others 2003). Seeds ripen sometime in August, and seed dispersal usually begins sometime between late August and mid-September (Hermann and Lavender 1990). Douglas-fir seeds are primarily wind-dispersed. Seeds germinate from mid-May to mid-June depending on elevation. A thin organic layer at the mineral soil surface creates a favorable environment for seedling establishment. Light shade encourages the germination and establishment of seedlings during the first year, especially on southerly slopes, by moderating temperature extremes. However, older seedlings require full sunlight. Generally speaking, in the southern and central Rocky Mountains, Rocky Mountain Douglas-fir is seral to subalpine fir and Engelmann spruce in colder, more moist environments at upper elevations and at sites experiencing cold air drainage, and is a climax species at warmer, drier sites at lower elevations.

In the central Rocky Mountains of Wyoming, historical fire return intervals in Douglas-fir forests range between 50 and 100 years (Steinberg 2002). Douglas-fir is most susceptible to fire in the seedling and sapling stage when the thin, resin filled bark is easily scorched through to the cambium. After about 40 years at moist sites, and perhaps 60 years in drier localities, Douglas-fir develops a thick, fire-resistant bark, at which point Douglas-fir can resist moderate intensity surface fires. However, if moderate intensity surface fires escalate into crown fires, Douglas-fir will be killed or severely damaged as buds and fine twigs are particularly susceptible to fire. Prescribed fire can be used to thin mature Douglas-fir forests, reduce fuel loadings, or halt the encroachment of Douglas-fir into adjacent grassland communities when mechanical thinning is logistically or monetarily prohibitive (Steinberg 2002). However, forest managers should proceed with caution for two reasons: (1) low to moderate severity controlled burns in early seral stands can quickly escalate into severe crown fires, and (2) post-fire mortality may occur as a result of western spruce budworm, Douglas-fir beetle (*Dendroctonus pseudotsugae*), and/or wood borer outbreaks, which typically follow light ground fires to moderate intensity burns.

Western spruce budworm, one of the most prolific insect pests of Rocky Mountain Douglas-fir, feeds on buds and needles of trees of all ages, often resulting in severe defoliation (Hermann and Lavender 1990). Adult and larval Douglas-fir beetles girdle and usually kill trees by feeding on the phloem layer (Hagle and others 2003). Douglas-fir beetle bore-holes provide an excellent avenue for the inoculation of the weakened trees with blue stain fungi. Trees not girdled and killed directly by the Douglas-fir beetle usually succumb to the blue stain fungi infection. Wood borers may include longhorned beetles (Family: Cerambycidae) and metallic wood borers (Family: Buprestidae). Longhorned beetles and metallic wood borers rarely kill their hosts; they usually only attack weakened and recently downed trees. The cambium is the first area of the host fed on by these wood boring insects. Tunnels are then sometimes extended into the sapwood.

Douglas-fir forests provide important habitat for a number of wildlife species (Steinberg 2002). A variety of songbirds, including Clark's nutcracker, black-capped and mountain chickadees, and red-breasted nuthatch, and small mammals, including red squirrels, chipmunks, mice, voles, and shrews, feed on the seeds of Douglas-fir. Blue grouse forage on Douglas-fir buds and needles.

Douglas-Fir/Rocky Mountain Maple, Redfist Family Ecological Type

Pseudotsuga menziesii var. *glauca/Acer glabrum*, Redfist Family Ecological Type

PSMEG/ACGL, Redfist Family ET

N = 6

Distribution

The Douglas-fir/Rocky Mountain Maple, Redfist Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from Sinks Canyon southeast to Limestone Mountain. It is a component of map unit 43L.

Environment

Aspect: North [3], northeast [1], north-northwest [2].

Landforms and Landscape Position: Backslopes and footslopes.

Parent Materials: Mixed limestone and dolomite colluvium.

Parent materials are typically mixed limestone and dolomite colluvium. However, in the depths of the Canyon Creek parent materials were mixed limestone and dolomite colluvium over Flathead Sandstone residuum.

Bedrock: Cambrian Flathead Sandstone, Cambrian Gros Ventre Shale, Cambrian Gallatin Limestone.

Flathead Sandstone was observed as bedrock at footslope positions along Canyon Creek from the junction of Spring Creek downstream to the Little Popo Agie River and along Sawmill Creek from the junction of Townsend Creek downstream to Crooked Creek. Other areas of Flathead Sandstone bedrock may occur along the lower section of other deep canyons along the eastern flank of the range.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 49 to 58 cm.

Additional environment data summaries are provided in Table 50.

Potential natural vegetation

The potential natural vegetation of this ecological type is the Douglas-fir/Rocky Mountain maple habitat type (Steele and others 1983). Douglas-fir dominates all canopy layer, especially in more mature stands. Limber pine and quaking aspen are usually present in the overstory of younger stands. Rocky Mountain maple, western serviceberry, and black chokecherry create an arbor-like tall shrub layer. Oregon grape and/or Oregon boxleaf are always present in the low shrub layer, sometimes at high abundance. Common juniper, russet buffaloberry, and Utah snowberry are shrubs common to early seral stands. As this habitat type matures, the less tolerant shrubs, including western serviceberry and black chokecherry, become less important and Rocky Mountain maple remains as the dominant shrub.

The herbaceous layer is similar to that described by Steele and others (1983) for this habitat type in eastern Idaho and far western Wyoming in that heartleaf arnica and bedstraw are the dominant herbaceous species. However, in the WRR, northern bedstraw (as opposed to fragrant bedstraw) is the primary bedstraw species. Additionally, elk sedge and pinegrass are rarely, if ever, present in this type. Rather, Wheeler's bluegrass, spike fescue, spike trisetum, and Ross' sedge are the primary graminoids. Other common species include Virginia strawberry, small-leaved alumroot, and alpine leafybract aster. Summaries of species constancy/cover and stand characteristics are provided in Tables 51 and 52, respectively.

Soils

Soils in the PSMEG/ACGL, Redfist Family ET were deep and calcareous, with a high degree of soil development, variable amounts of rock fragments (27–78%, avg. 56%), moderate to high clay (17–32%, avg. 24%), and strong clay illuviation into subsurface soil horizons. A thin (avg. 5 cm thick) litter layer occurred at the surface. Soils with a calcic horizon typically featured an A/Btk-Bk/BC-C horizonation. One soil featured a 29-cm thick Bw-horizon and 15-cm thick Bt-horizon directly below the A-horizon and above a Btk-horizon. Diagnostic soil horizons include an ochric epipedon (avg. 22 cm thick), and a calcic horizon (avg. 47 cm thick). One soil displayed a 45-cm thick mollic epipedon. Particle size class was loamy-skeletal. Soils were Typic Calciustepts [1], Pachic Haplustolls [1], Calcic Haplustepts [1], and Calcic Haplustalfs [1].

Soils lacking calcic horizons typically featured an A/Bt/C horizonation. C-horizons tended to be thick (avg. 68 cm thick), and extremely gravelly. Diagnostic soil horizons include a mollic (36 cm thick) or ochric epipedon (14 cm thick), and a thin argillic horizon (avg. 17 cm thick). Particle size class was fine-loamy. The soils were classified as clay-rich Mollisols and weak Alfisols, including Typic Argiustolls [1] and Inceptic Haplocryalfs [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Calcic Haplustepts

Oi—0 to 4 cm: slightly decomposed plant material; abrupt wavy boundary.

A—4 to 18 cm: brown (10YR 5/3) silt loam, dark brown (10YR 3/3), moist; 41% sand; 20% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; patchy faint carbonate coats on rock fragments; 1% fine faint carbonate nodules in matrix; 6% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly alkaline, pH 7.4; clear wavy boundary.

AB—18 to 33 cm: pale brown (10YR 6/3) very gravelly silt loam, yellowish brown (10YR 5/4), moist; 40% sand; 22% clay; weak medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, hard, moderately sticky, moderately plastic; common fine roots and common medium roots and common very coarse roots and common very fine roots; common fine and common medium and common very coarse and common very fine pores; patchy distinct carbonate coats on rock fragments; 25% fine faint carbonate nodules in matrix; 22% 251- to 600-mm unspecified fragments and 45% 2- to 75-mm unspecified fragments; slight effervescence, by HCl, 1 normal; moderately alkaline, pH 8.1; clear wavy boundary.

Bk—33 to 71 cm: light brown (7.5YR 6/3) extremely stony loam, strong brown (7.5YR 4/6), moist; 39% sand; 26% clay; weak medium subangular blocky structure, and weak fine granular structure; friable, slightly hard, slightly sticky, moderately plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; patchy distinct carbonate coats on bottom surfaces of rock fragments; 1% fine faint carbonate nodules in matrix; 28% 251- to 600-mm unspecified fragments and 44% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.1; abrupt smooth boundary.

2BC—71 to 103 cm: pale yellow (2.5Y 7/4) extremely gravelly sandy loam, light olive brown (2.5Y 5/6), moist; 69% sand; 16% clay; weak medium subangular blocky structure, and weak very fine granular structure; very friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots; common fine and common medium and common coarse pores; 3% 251- to 600-mm unspecified fragments and 85% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.0.

Ecology

The PSMEG/ACGL, Redfist Family ET was distributed on north-facing slopes along the lower reaches of steep canyons near lower tree line. Topography, including elevation, slope gradient, and slope aspect, as it influences climatic factors responsible for regulating soil moisture, is very important in the spatial distribution of Rocky Mountain Douglas-fir in the central and southern Rocky Mountains, especially at the lower elevation extent (1,800–2,800 m). At lower elevations in the central and southern Rocky Mountains, contiguous stands of Rocky Mountain Douglas-fir are generally limited to cooler, more moist north-facing slopes (Hermann and Lavender 1991).

Rocky Mountain maple is a moist site indicator in the mountains of western Wyoming (Houston and others 2001). Considering that in mountainous regions precipitation generally decreases with elevation, the spatial distribution of Rocky Mountain maple at lower elevations along canyon walls suggests that these sites are more mesic than is characteristic for these lower elevations. Precipitation in mountainous regions that are dominated by steep, narrow canyons can be effected by a phenomenon termed “canyon effects” (Baker 1944). Canyon effects occur when moist air masses, uplifted by the higher elevation ridges surrounding a canyon, result in elevated amounts of precipitation at the canyon bottom. Canyon effects may partly explain the distribution of Rocky Mountain maple in these lower elevation Douglas-fir forests. The clay-rich soils, which retain moisture well into the summer months, may also help explain the distribution of this ET.

Mollisols are most commonly associated with soils in grassland and sagebrush communities (Nimlos and Tomer 1982). However, a handful of Mollisols occurred under north-facing conifer stands, sites more typical of Alfisols, including two sample sites in the PSMEG/ACGL, Redfist Family ET. Quaking aspen is seral to Douglas-fir in this ET following forest fire, and the early seral stages of these forested stands feature vigorous quaking aspen resprouts. Quaking aspen leaves, which have high concentrations of cations and decompose quickly due to a low carbon to nitrogen ratio, contribute strongly to the development of thick, dark, carbon-rich surface horizons with relatively high pH (typically >6.0) (Cryer and Murray 1992; Howard 1996; Legare and others 2005). The abundance of deciduous shrubs in later seral stages of the PSMEG/ACGL, Redfist Family ET, including Rocky Mountain maple, Utah snowberry, and black chokecherry, likely contribute to the persistence of Mollisols through the annual input of highly decomposable, carbon-rich leaf litter.

Succession

The sample sites in the PSMEG/ACGL, Redfist Family ET fall within successional stages (D) through (E) described below. Sample sites with low basal area (10–30 ft^2/acre) of Douglas-fir and moderate to high basal area (>30 ft^2/acre) of quaking aspen fall within successional stage (D). Sample sites with moderate to high basal area (>30 ft^2/acre) of Douglas-fir and low basal area of quaking aspen (10–30 ft^2/acre) fall within successional stage (E). Sample sites with no quaking aspen fall within successional stage (F).

Quaking aspen is a common seral species in these moist Douglas-fir forests. In soils influenced by sandstone, lodgepole pine may also occur in early seral stands. A brief herbaceous/shrub stage (A) follows directly after a stand replacing burn and is quickly replaced by a dense stand of aspen resprouts (B) (Bradley and others 1992). A fire of any intensity during stage (B) will reset the successional pathway. In the absence of fire, stage (B) is followed by a dense, pole-sized aspen stand that features Douglas-fir seedlings in the understory (C). Low fires result in a more open stand in which aspen and Douglas-fir seedlings can become established. Moderate fires reset the successional pathway, resulting in a dense stand of aspen resprouts. A mixed stand (D) develops in the absence of fire, in which Douglas-fir dominates the understory and shares the overstory with aspen. A moderate fire at stage (D) eliminates the understory, killing aspen stems and creating an open Douglas-fir stand with aspen resprouts (D1). The stand is maintained by low fire, while severe fire will completely reset the successional pathway. In the absence of fire, quaking aspen will eventually begin to break up as Douglas-fir continues to shade the understory to the detriment of quaking aspen resprouts (E). In the continued absence of fire, a climax multi-aged Douglas-fir stand develops (F). Moderate fires at stage (F) result in a more open Douglas-fir forest with scattered aspen in canopy openings. Severe fire will completely reset the successional pathway.

Management considerations

The PSMEG/ACGL, Redfist Family ET is moderately well suited for timber harvest. Basal area and trees per ha are high and the deep soils are highly productive. However, these sites typically feature a steep slope gradient (avg. 46%), thus reducing operability of heavy timber harvest equipment.

Since Douglas-fir is a wind-dispersed species that regenerates most favorably in small canopy openings, silvicultural techniques should be used that leave suitable seed trees and result in small forest gaps, such as individual tree selection or shelterwood cuts. Group selection or shelterwood cuts are appropriate silvicultural techniques in mixed Douglas-fir and lodgepole pine stands (Steinberg 2002). Clear-cutting can be used to salvage entire stands damaged by insects or Douglas-fir dwarf mistletoe. Following clear-cutting of infested stands, slash should be burned in piles or windrows in order to control residual dwarf mistletoe and insects.

Mechanical thinning of well-stocked, multi-storied stands can reduce the potential for intensive western spruce budworm attack (Bradley and others 1992). Prescribed fire can be used to thin mature Douglas-fir forests, reduce fuel loadings, or halt the encroachment of Douglas-fir into adjacent grassland communities when mechanical thinning is logistically or monetarily prohibitive (Steinberg 2002). However, forest managers should proceed with caution for two reasons: (1) low to moderate severity controlled burns in early seral stands can quickly escalate into severe crown fires, and (2) post-fire mortality may occur as a result of western spruce budworm, Douglas-fir beetle, and/or wood borer outbreaks that typically follow light ground fires to moderate intensity burns.

Managers considering the use of prescribed fire to increase the abundance of Rocky Mountain maple should consider using low to moderate intensity burns as high intensity burns can result in less successful regeneration and an overall loss of vigor. Silvicultural treatments, including thinning, clear-cutting, and shelterwood cuts, may also lead to an increase in the overall density of Rocky Mountain maple. However, severe damage to the root crown due to mechanical disturbance will decrease the abundance of Rocky Mountain maple following silvicultural treatments. Rocky Mountain maple is an important browse species for domestic and wild ungulates and, in early seral stands, provides physical and thermal cover for a variety of wildlife, including mule deer, elk, birds, and small mammals (Anderson 2001a). Lastly, where this ET is underlain by Gros Ventre Shale bedrock, landslide potential is high, especially following a wetter than normal winter/spring on steep (approximately >35%), recently burned slopes.

Similar ecological types

Ecological Type 1

Type: Douglas-fir/Rocky Mountain Maple, Yourame Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the soils of the Redfist Family ET are derived from mixed calcareous colluvium or mixed calcareous colluvium over residuum, while the soils of the Yourame Family ET are derived from mixed calcareous colluvium over granitic glacial till.

Table 50—Summary of environmental variables for the PSMEG/ACGL, Redfist Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,422	2,273	2,493
Slope (%)	46	40	56
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	552	490	581
Degree days	18,700	17,890	20,560
Frost-free days	20.8	20.4	21.8
Site water balance (mm/year)	-246	-277	-207
Average annual temperature (°C)	2.7	2.4	3.5
Total annual potential evapotranspiration (mm)	560	504	594
Summer radiation (KJ)	17,750	16,490	18,320
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	56	27	78
Clay (% in particle size control section)	24	17	32
pH (in particle size control section)	7.5	7.0	8.0
Available Water Capacity (mm/m)	68	47	137
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	4	1	7
Exposed bedrock	1	0	5
Gravel	3	0	10
Cobble	4	1	10
Stones	4	2	5
Boulders	13	3	20
Litter	17	15	20
Wood	13	10	15
Moss and lichen	2	1	3
Basal vegetation	38	20	60
Water	0	0	0

Table 52—Stand characteristics for the PSMEG/ACGL, Redfist Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m²/ha---		*-------Centimeters-------*			
ABLA	2.3	—	12.7	—	180	—
PIFL2	6.9	—	27.7	22.9–35.8	128	—
POTR5	5.3	2.3–11.5	15.5	11.7–16.5	299	121–561
PSMEG	16.1	2.3–27.6	34.0	13.5–64.3	259	17–773

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
ABLA	12.7	8	38
PIFL2	24.4	—	76
POTR5	14.5	17	—
PSMEG	37.3	24	85

Table 51—Constancy/cover table for common plant species occurring in the PSMEG/ACGL, Redfist Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	20	10	30
Subdominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	50	4	2	5
POTR5	*Populus tremuloides*	quaking aspen	50	10	5	15
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	50	2	1	3
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	4	1	10
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	50	2	1	3
POTR5	*Populus tremuloides*	quaking aspen	50	2	1	3
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	83	4	3	5
Shrubs:						
ACGL	*Acer glabrum*	Rocky Mountain maple	100	6	5	10
AMAL2	*Amelanchier alnifolia*	western serviceberry	50	2	1	3
JUCOD	*Juniperus communis* var. *depressa*	common juniper	100	4	1	5
MARE11	*Mahonia repens*	Oregon grape	100	6	1	10
PAMY	*Paxistima myrsinites*	Oregon boxleaf	50	6	3	10
PRVIM	*Prunus virginiana* var. *melanocarpa*	black chokecherry	50	3	1	7
ROWO	*Rosa woodsii*	woods rose	100	2	1	3
SHCA	*Shepherdia canadensis*	russet buffaloberry	100	12	3	25
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	83	5	1	15
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	11	3	25
FRSP	*Frasera speciosa*	elkweed	50	2	1	3
FRVI	*Fragaria virginiana*	Virginia strawberry	100	2	1	3
GABO2	*Galium boreale*	northern bedstraw	100	2	1	3
HEPA11	*Heuchera parvifolia*	small-leaved alumroot	83	1	1	1
ORSE	*Orthilia secunda*	sidebells wintergreen	50	2	1	3
PAST10	*Packera streptanthifolia*	Rocky Mountain groundsel	50	1	1	1
POGL9	*Potentilla glandulosa*	sticky cinquefoil	50	1	1	1
SYFO2	*Symphyotrichum foliaceum*	alpine leafybract aster	100	4	1	5
VIOLA	*Viola*	violet	67	1	1	1
Grasses:						
ELGL	*Elymus glaucus*	blue wildrye	50	4	3	5
LEKI2	*Leucopoa kingii*	spike-fescue	67	2	1	3
POWH2	*Poa wheeleri*	Wheeler's bluegrass	83	3	1	3
TRSP2	*Trisetum spicatum*	spike trisetum	67	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Douglas-Fir/Oregon Grape, Cloud Peak Family Ecological Type

Pseudotsuga menziesii var. *glauca/Mahonia repens*, Cloud Peak Family Ecological Type

PSMEG/MARE11, Cloud Peak Family ET

N = 6

Distribution

The Douglas-fir/Oregon grape, Cloud Peak Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from Sinks Canyon southeast to Limestone Mountain. It is a component of map unit 43L. This ecological type occurs on moderately steep (approximately 20–40%), north- and east-facing limestone footslopes, backslopes and shoulders.

Environment

Aspect: East [1], north [2], north-northeast [2], north-northwest [1]

Landforms and Landscape Position: Shoulders, backslopes, footslopes.

Parent Materials: Limestone or dolomite colluvium.

Bedrock: Madison or Gallatin Limestone.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation ranges from 56 to 63 cm.

Additional environment data summaries are provided in Table 53.

Potential natural vegetation

The potential natural vegetation of this ET is the Douglas-fir/Oregon grape habitat type. The Oregon grape phase is the primary phase associated with this ET; however, the common juniper phase may also occur (Steele et. al 1983). Douglas-fir occurs in all canopy layers, forming a dense tree canopy and exhibiting vigorous regeneration in the understory. Limber pine commonly occurs at low abundance scattered throughout the understory canopy layer, and sometimes occurs as a subdominant in the overstory.

Oregon grape and Oregon boxleaf often co-occur forming a diffuse low shrub layer. Russet buffaloberry, Utah snowberry, and common juniper may also be present in the shrub layer at low abundance. The presence of black chokecherry is indicative of early seral stages of this ET. Heartleaf arnica, northern bedstraw, Wheeler's bluegrass, and Ross' sedge are the most common herbaceous species found in this ET. Sticky purple geranium is sometimes found in this ET and is a moist site indicator.

One site, located on an east-facing shoulder was characterized by small (≤0.04 ha) canopy openings scattered throughout the stand. The vegetation composition of the openings resembled that of a grassland or sagebrush community, including mountain big sagebrush, arrowleaf balsamroot, bluebunch wheatgrass, and spike fescue. Species from these openings were also found growing under the forested canopy at low abundance. This site likely represents a mid-fire seral stage in which the vegetation is transitioning from sagebrush-grassland to an open forest canopy. Summaries of species constancy/cover and stand characteristics are provided in Tables 54 and 55, respectively.

Soils

Soils in the PSMEG/MARE11, Cloud Peak Family ET are highly calcareous, deep, and feature a high degree of soil development, moderate amounts of coarse fragments (avg. 50%), and strong subsurface clay accumulations (avg. 25%). A thin (avg. 3 cm thick) litter layer occurs at the surface. A typical soil features an A/Bt-Btk/Bk horizonation. Diagnostic soil horizons include a thin ochric epipedon (avg. 9 cm thick), an argillic horizon (avg. 32 cm thick), and a calcic horizon (avg. 38 cm thick). One soil featured a mollic epipedon (27 cm thick). Particle size class was primarily loamy-skeletal with one soil of the fine-loamy class. The soils were classified as Alfisols and clay-rich Mollisols, including Calcic Haplustalfs [3], Ustic Haplocryalfs [1], Inceptic Haplustalfs [1], and Typic Argiustolls [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, Ustic Haplocryalfs

<u>Oi—0 to 1 cm</u>: slightly decomposed plant material; abrupt smooth boundary.

<u>A—1 to 5 cm</u>: dark grayish brown (10YR 4/2) very fine sandy loam, very dark grayish brown (10YR 3/2), moist; 66% sand; 11% clay; weak thick platy structure, and weak thin platy structure; friable, slightly hard, slightly sticky, nonplastic; many very fine roots; many very fine pores; 4% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; neutral, pH 6.9; clear wavy boundary.

<u>Bt1—5 to 11 cm</u>: brown (10YR 5/3) cobbly sandy clay loam, dark brown (10YR 3/3), moist; 57% sand; 21% clay; weak medium subangular blocky structure, and weak fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 2% patchy faint clay films on all faces of peds; 8% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 10% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; neutral, pH 7.1; clear wavy boundary.

<u>Bt2—11 to 31 cm</u>: yellowish brown (10YR 5/4) very gravelly sandy clay loam, brown (10YR 4/3), moist; 59% sand; 23% clay; weak medium subangular blocky structure, and moderate very fine subangular blocky structure; firm, moderately hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots and common coarse roots and common very coarse roots; common very fine and fine and common medium and common coarse and common very coarse pores; patchy faint clay films on rock fragments and 14% patchy faint clay films on all faces of peds; 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 28% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.4; clear irregular boundary.

<u>Btk—31 to 64 cm</u>: light yellowish brown (10YR 6/4) extremely gravelly sandy clay loam, yellowish brown (10YR 5/4), moist; 69% sand; 22% clay; weak fine subangular blocky structure, and weak very fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; patchy distinct carbonate coats on rock fragments and 2% patchy faint clay films on surfaces along root channels; 7% fine faint carbonate masses in matrix; 10% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 17% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 39% nonflat subrounded indurated 2- to 75-mm unspecified fragments; slight effervescence; slightly alkaline, pH 7.6; gradual wavy boundary.

<u>Bk—64 to 104 cm</u>: very pale brown (10YR 7/4) extremely cobbly sandy loam, yellowish brown (10YR 5/4), moist; 77% sand; 17% clay; weak very fine subangular blocky structure, and; friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; patchy distinct carbonate coats on rock fragments; 18% fine faint carbonate masses in matrix; 9% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 28% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 29% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.1.

Ecology

Topography, including elevation, slope gradient, and slope aspect, as it influences climatic factors responsible for regulating soil moisture, is very important in the spatial distribution of Rocky Mountain Douglas-fir in the central and southern Rocky Mountains, especially at the lower elevation extent (1,800–2,800 m). At lower elevations in the central and southern Rocky Mountains, contiguous stands of Rocky Mountain Douglas-fir are generally limited to cooler, more moist north-facing slopes (Hermann and Lavender 1991). The clay-rich soils have high available water-holding capacity, which help maintain high soil moisture well into the summer months. Oregon grape, which is tolerant of full sun and partial to deep shade, is often the only shrub species able to tolerate the intense shade experienced in the understory of this ET (Uley 2006).

Mollisols are most commonly associated with soils in grassland and sagebrush communities (Nimlos and Tomer 1982). However, a handful of Mollisols occurred under north-facing conifer stands, sites more typical of Alfisols, including one sample site in the PSMEG/MARE11, Cloud Peak Family ET. The vegetation communities on these north-facing forested Mollisols were typified by more open overstories and relatively high abundance of grass in the understories. The grassland influence at these sites may be associated with forest fire and represent the early to middle stages of the transition between grassland and forest.

Succession

Across the majority of the eastern slope of the WRR, Douglas-fir is the primary species regenerating in the PSMEG/MARE11, Cloud Peak Family ET following disturbance. However, on soils with a sandstone influence, or at more mesic sites, lodgepole pine or quaking aspen may be important seral species, respectively. Where lodgepole pine is seral to Douglas-fir, a likely successional pathway begins with a brief herbaceous/shrub stage (A) directly after a stand replacing burn, followed by a Douglas-fir and lodgepole pine seedling and sapling stage (B) (Bradley and others 1992). A fire of any intensity during stage (B) will reset the successional pathway. In the absence of fire, stage (B) is followed by a dense Douglas-fir and lodgepole pine pole stand (C). The absence of fire leads to a young mature Douglas-fir and lodgepole pine stand (D) followed by an older mature Douglas-fir forest with scattered lodgepole pine and strong Douglas-fir regeneration (F) and eventually a multi-storied climax Douglas-fir forest (G). A moderate to severe fire at stage (C) will reset the successional pathway, while a low severity fire will result in a scattered pole stand with lodgepole pine and Douglas-fir regeneration in the understory (C1). Continual low severity burns will maintain the scattered pole stand. In the absence of fire, stage (C1) will shift to an open Douglas-fir stand with Douglas-fir and lodgepole pine regeneration (D1), and eventually a mature Douglas-fir and lodgepole forest with strong Douglas-fir regeneration (E1). At stages (D), (D1), (E1), and (F), a moderate severity fire will result in an open Douglas-fir stand (E), which is maintained by a fire of any intensity. In the absence of fire, the (E1) stage shifts to stage (F), and eventually to a multi-storied climax Douglas-fir forest (G). The fire resistance of Douglas-fir and lodgepole pine increases as diameter increases, and as such, low severity fires have little influence on stand structure beyond stage (D). Beyond stage (D), severe fires will completely reset the successional pathway.

Where quaking aspen is seral to Douglas-fir, an early herbaceous/shrub stage (A) gives way quickly to a dense stand of aspen resprouts with Douglas-fir seedlings in canopy openings (B) (Bradley and others 1992). A fire of any severity at stage (B) will reset the successional pathway. In the absence of fire, a pole-sized quaking aspen stand will develop with Douglas-fir in the understory (C). A moderate severity fire at stage (C) will return the stand to stage (B), while low severity fires will maintain the pole-sized stand. In the absence of fire, a mixed quaking aspen and Douglas-fir stand develops with strong Douglas-fir regeneration (D). A low severity fire at stage (D) will maintain the mixed stand while a moderate severity fire will lead to an open Douglas-fir forest with quaking aspen resprouts (D1). Low to moderate severity fires at stage (D1) will maintain the open Douglas-fir forest, while in the absence of fire, the stand will eventually return to stage (D). The absence of fire beyond stage (D) leads to the break-up of the quaking aspen overstory (E) and eventually to a climax Douglas-fir forest with quaking aspen reduced to meager patches occurring in small canopy openings in the understory. A severe fire beyond stage (C) will completely reset the successional pathway.

Management considerations

The PSMEG/MARE11, Cloud Peak Family Family ET shows the most promise for timber harvest of all Ecological Types in the Douglas-fir series. Basal area and trees per ha are high, and the deep, clay-rich soils are highly productive. These sites also typically feature low to moderate slope gradient (<30%) and very little rock outcrop, making this ET accessible to logging equipment. However, the clay-rich soils are at increased risk of compaction by heavy logging equipment. Soil compaction can lead to reduced rates of water infiltration, decreased pore space, and lower soil volume, factors resulting in reduced root penetration and overall water availability (Meurisse and others 1991).

Since Douglas-fir is a wind-dispersed species that regenerates most favorably in small canopy openings, silvicultural techniques should be used that leave suitable seed trees and result in small forest gaps, including individual tree selection or shelterwood cuts. Group selection or shelterwood cuts are appropriate silvicultural techniques in mixed Douglas-fir and lodgepole pine stands (Steinberg 2002). Clear-cutting can be used to salvage entire stands damaged by insects or Douglas-fir dwarf mistletoe. Following clear-cutting of infested stands, slash should be burned in piles or windrows in order to control residual dwarf mistletoe and insects.

Mechanical thinning of well-stocked, multi-storied stands can reduce the potential for intensive western spruce budworm attack (Bradley and others 1992). Prescribed fire can be used to thin mature Douglas-fir forests, reduce fuel loadings, or halt the encroachment of Douglas-fir into adjacent grassland communities when mechanical thinning is logistically or monetarily prohibitive (Steinberg 2002). However, forest managers should proceed with caution for two reasons: (1) low to moderate severity controlled burns in early seral stands can quickly escalate into severe crown fires, and (2) post-fire mortality may occur as a result of western spruce budworm, Douglas-fir beetle, and/or wood borer outbreaks that typically follow light ground fires to moderate intensity burns.

Oregon grape with its ability to resprout from underground rhizomes, is well adapted to forest fire and logging disturbance. Low to moderate severity burns actually stimulate Oregon grape growth, often resulting in increased vigor in the years immediately following a fire. Also, forest fires may result in the germination of Oregon grape seeds stored in the seed bank. However, severe burns that remove the duff layer and heat the upper mineral soil may kill the underground rhizomes, resulting in Oregon grape mortality.

Deer trails were commonly observed in this ET. Following severe fire, this ET may provide moderate amounts of forage. However, forage production drops continually as stand age increases, and Oregon grape may be the only species with appreciable forage value in climax stands.

Similar ecological types

Ecological Type 1

Type: Subalpine fir/Oregon grape, Frisco Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Frisco Family ET is subalpine fir, while the potential natural vegetation of the Cloud Peak Family ET is Douglas-fir.

Environmental differences: The two types differ in that the Frisco Family ET occurs at slightly higher elevations (avg. 2,666 m) and experiences lower degree days (avg. 15,720) and average annual temperature (avg. 1.6 ºC) than the Cloud Peak Family ET, which occurs at an average elevation of 2,582 m, and experiences higher degree days (avg. 17,350) and average annual temperature (2.2 ºC).

Table 53—Summary of environmental variables for the PSMEG/MARE11, Cloud Peak Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,582	2,442	2,639
Slope (%)	29	9	41
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	600	556	628
Degree days	17,350	16,340	18,690
Frost-free days	20.1	19.6	20.8
Site water balance (mm/year)	-240	-266	-219
Average annual temperature (°C)	2.2	1.8	2.7
Total annual potential evapotranspiration (mm)	564	531	615
Summer radiation (KJ)	18,300	16,440	19,150
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	50	28	66
Clay (% in particle size control section)	25	20	29
pH (in particle size control section)	7.6	7.0	7.9
Available water capacity (mm/m)	66	46	114
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	1	0	5
Exposed bedrock	0	0	0
Gravel	2	0	3
Cobble	3	1	5
Stones	1	0	2
Boulders	1	0	5
Litter	56	22	70
Wood	16	5	40
Moss and lichen	1	0	4
Basal vegetation	17	10	20
Water	0	0	0

Table 54—Constancy/cover table for common plant species occurring in the PSMEG/MARE11, Cloud Peak Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	83	30	15	40
Subominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	50	2	1	3
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	83	20	10	45
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	67	2	1	3
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	5	1	15
Seedlings:						
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	83	2	1	5
JUCOD	*Juniperus communis* var. *depressa*	common juniper	83	2	1	3
Shrubs:						
MARE11	*Mahonia repens*	Oregon grape	100	5	3	10
PAMY	*Paxistima myrsinites*	Oregon boxleaf	83	3	1	5
ROWO	*Rosa woodsii*	woods rose	50	1	1	1
SHCA	*Shepherdia canadensis*	russet buffaloberry	83	4	1	10
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	67	2	1	3
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	3	3	5
FRVI	*Fragaria virginiana*	Virginia strawberry	50	1	1	1
GABO2	*Galium boreale*	northern bedstraw	67	2	1	3
SYFO2	*Symphyotrichum foliaceum*	alpine leafybract aster	50	1	1	1
Grasses:						
ACNE9	*Achnatherum nelsonii*	Columbia needlegrass	50	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	83	1	1	3
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	67	2	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 55—Stand characteristics for the PSMEG/MARE11, Cloud Peak Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---*m*^{2}*/ha*---		-------*Centimeters*-------			
PICOL	20.1	—	19.8	15.2–25.1	709	—
PIFL2	2.3	—	29.7	—	32	—
PSMEG	34.4	25.3–39.0	30.0	14.7–54.6	595	388–731

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PICOL	19.8	12	120
PIFL2	—	—	—
PSMEG	35.6	19	191

Douglas-Fir/Common Juniper, Shawmut Family Ecological Type

Pseudotsuga menziesii var. *glauca/Juniperus communis* var. *depressa*, Shawmut Family Ecological Type

PSMEG/JUCOD, Shawmut Family ET

N = 5

Distribution

The Douglas-fir/common juniper, Shawmut Family Ecological Type occurs in the northern and southern study areas within the dry, mid-elevation, sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 12L. This ecological type occurs on northeast-facing Madison Limestone and Bighorn dolomite summits, including Fairfield Hill, Fossil Hill, and Peak 9239 on Freak Mountain. This type also occurs on south-facing shoulders in a distinct narrow band located below the Bighorn Dolomite outcrops and above the Gallatin Limestone Formation, including areas around Fairfield Hill, Fossil Hill, Peak 9378 south of Elderberry Creek headwaters, Freak Mountain, Ed Young Mountain, and Limestone Mountain.

Environment

Aspect: Northeast [1], north-northeast [1], northwest [1], south-southwest [1], southwest [1].

Landforms and Landscape Position: Shoulders and summits.

Parent Materials: Colluvium and residuum.

When this ET occurs on summits, parent materials tend to be Madison Limestone or Bighorn Dolomite colluvium over residuum.

When this ET occurs on shoulders, parent materials tend to be mixed Bighorn Dolomite and Gallatin Limestone colluvium over Gallatin Limestone residuum.

Bedrock: Cambrian and Mississippian Limestones, Ordovician Dolomite.

Climate: Cryic temperature regime and Udic moisture regime on summits and shoulders over approximately 2750 m elevation and/or northerly aspects. At elevations below approximately 2750 m elevation and/or on southerly aspects, soil temperature regime is Frigid, and soil moisture regime is Ustic. Estimated annual precipitation ranges from 66 to 68 cm.

Additional environment data summaries are provided in Table 56.

Potential natural vegetation

The potential natural vegetation of this ecological type is the Douglas-fir/common juniper habitat type (Steele and others 1983). Douglas-fir is the projected climax dominant tree species. Limber pine and occasionally lodgepole pine occur as early seral species, although limber pine is often present at low abundance in the overstory of mature stands as well. Quaking aspen occurs sporadically in the understory layer. Canopy cover of tree species ranges between 35 and 75%.

Common juniper and Utah snowberry are the most common shrub species encountered. Shrub species more typical of early seral stands include mountain big sagebrush, antelope bitterbrush, and russet buffaloberry. Rocky Mountain maple is indicative of more mesic microsites. Total canopy cover for shrub species ranges between 10 and 30%. Common herbaceous species include heartleaf arnica, Henderson's wavewing, spike fescue, and Ross' sedge. Arrowleaf balsamroot is indicative of earlier seral stages. Small-leaved alumroot, when it occurs, may be found exclusively on dolomite boulders. Summaries of species constancy/cover and stand characteristics are provided in Tables 57 and 58, respectively.

Soils

Soils in the PSMEG/JUCOD, Shawmut Family ET are deep and carbonate rich, with a high degree of soil development, low to moderately high coarse fragments (15-66%, avg. 46%), high clay (avg. 25%), dark brown upper soil horizons, brown to yellowish lower soil horizons, and strong clay illuviation into subsurface soil horizons. A thin (avg. 2 cm thick) litter layer occurs at the surface. A typical soil features an A/Bt-Btk/Bk horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 12 cm thick), an argillic horizon (avg. 65 cm thick), and a calcic horizon (avg. 44 cm thick). Two soils featured thick mollic epipedons (avg. 24 cm thick). Particle size class was primarily

loamy-skeletal [4] with one soil of the fine-loamy class. The soils were classified as clay-rich Mollisols and Alfisols, including Calcic Argicryolls [1], Typic Argiustolls [1], Eutric Haplocryalfs [2], and Typic Haplustalfs [1].

Typical pedon description

Soil Classification: Loamy-skeletal, Deep, Typic Argiustolls

Oe–0 to 3 cm: moderately decomposed plant material; abrupt wavy boundary.

A–3 to 7 cm: very dark grayish brown (10YR 3/2) loam, black (10YR 2/1), moist; 51% sand; 18% clay; moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common very fine roots; common very fine and fine and common medium pores; 5% nonflat subrounded indurated 76- to 250-mm unspecifiedfragments and 6% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; neutral, pH 7.0; abrupt wavy boundary.

Bat–7 to 27 centimeter: dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2), moist; 45% sand; 23% clay; moderate medium subangular blocky structure, and moderate very fine subangular blocky structure; firm, moderately hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots and common coarse roots; common very fine and fine and common medium and common coarse pores; 2% patchy faint clay films on all faces of peds; 3% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 5% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; neutral, pH 7.1; clear wavy boundary.

Bt1–27 to 39 cm: yellowish brown (10YR 5/4) and yellowish brown (10YR 5/6) very gravelly clay loam, brown (10YR 4/3) and dark yellowish brown (10YR 4/6), moist; 43% sand; 33% clay; moderate coarse subangular blocky structure, and moderate fine subangular blocky structure; firm, extremely hard, moderately sticky, very plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very coarse and common very fine pores; 20% patchy faint clay films on all faces of peds; carbonate, finely disseminated throughout; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 8% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 30% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.4; clear wavy boundary.

2Bt2–39 to 64 cm: light brown (7.5YR 6/4) very gravelly sandy clay loam, brown (7.5YR 4/4), moist; 58% sand; 25% clay; weak medium subangular blocky structure, and moderate very fine subangular blocky structure; friable, moderately hard, moderately sticky, moderately plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 15% patchy faint clay films between sand grains; carbonate, finely disseminated throughout; 10% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 13% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 36% nonflat subrounded indurated 2-to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.6; clear wavy boundary.

2Btk–64 to 89 cm: brown (7.5YR 5/4) very stony sandy clay loam, brown (7.5YR 4/3), moist; 60% sand; 21% clay; moderate fine subangular blocky structure, and moderate very fine subangular blocky structure; friable, hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common coarse roots; common fine and common medium and common coarse and common very fine pores; 20% patchy faint clay films on all faces of peds; 12% fine distinct carbonate masses in matrix; 12% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 16% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 22% nonflat subrounded indurated 2- to 75-mm unspecified fragments; slight effervescence; slightly alkaline, pH 7.8; gradual wavy boundary.

2Bk–89 to 106 cm: pale brown (10YR 6/3) extremely stony sandy clay loam, brown (10YR 5/3), moist; 59% sand; 20% clay; weak fine subangular blocky structure; very friable, slightly hard, slightly sticky, slightly plastic; common medium roots; common very fine and fine and common medium pores; 40% patchy distinct carbonate coats on bottom surfaces of rock fragments; 30% fine distinct carbonate masses in matrix; 6% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 13% nonflat subrounded indurated 2-to 75-mm unspecified fragments and 43% nonflat subrounded indurated 250- to 600-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.0.

Ecology

Douglas-fir is a wind-dispersed species with relatively higher physiological moisture requirements than limber pine. Across the eastern flank of the WRR, contiguous stands of Douglas-fir are generally limited to cooler, more moist north-facing limestone slopes. Douglas-fir forests only occasionally extend onto southerly slopes where soil conditions provide for higher water holding capacity, as is the case with the PSMEG/JUCOD, Shawmut Family ET. The clay-rich soils located on south-facing Gallatin shoulders retain moisture long into the summer months, allowing Douglas-fir to extend its distribution onto these otherwise drought-stricken sites.

Common juniper is a widespread conifer species and includes five subspecies or varieties occurring on all major continents throughout the northern hemisphere (Pojar and Mackinnon 1994). The variety *Juniperus communis* var. *depressa* is present in the Rocky Mountains and is a low shrub typically 3 m tall or less. Common juniper is intolerant of shade and prefers relatively open canopy forested communities with high amounts of solar radiation (Ward 1982).

Succession

Across the majority of the eastern slope of the WRR, Douglas-fir is the primary species regenerating in the PSMEG/JUCOD, Shawmut Family ET following disturbance. Limber pine often co-dominates with Douglas-fir at all developmental stages. Where lodgepole pine is seral to Douglas-fir, a likely successional pathway begins with a brief herbaceous/shrub stage (A) directly after a stand replacing burn, followed by a Douglas-fir and limber pine seedling and sapling stage (B) (Bradley and others 1992). A fire of any intensity during stage (B) will reset the successional pathway. In the absence of fire, stage (B) is followed by a dense Douglas-fir and limber pine pole stand (C). The absence of fire leads to a young mature Douglas-fir and limber pine stand (D), followed by an older mature Douglas-fir forest with abundant limber pine and strong Douglas-fir regeneration (F), and eventually a multi-storied climax Douglas-fir forest (G). A moderate to severe fire at stage (C) will reset the successional pathway, while a low severity fire will result in a scattered pole stand with limber pine and Douglas-fir regeneration in the understory (C1). Continual low severity burns will maintain the scattered pole stand. In the absence of fire, stage (C1) will shift to an open Douglas-fir stand with Douglas-fir and limber pine regeneration (D1) and eventually a mature Douglas-fir and limber pine forest with strong Douglas-fir regeneration (E1). At stages (D), (D1), (E1), and (F), a moderate severity fire will result in an open Douglas-fir stand (E), which is maintained by a fire of any intensity. In the absence of fire, the (E1) stage shifts to stage (F) and eventually to a multi-storied climax Douglas-fir forest (G). The fire resistance of Douglas-fir and limber pine increases as diameter increases, and as such, low severity fires have little influence on stand structure beyond stage (D). Beyond stage (D), severe fires will completely reset the successional pathway.

Management considerations

In the central Rocky Mountains of Wyoming, historical fire return intervals in Douglas-fir forests ranges between 50 and 100 years (Steinberg 2002). Douglas-fir is most susceptible to fire in the seedling and sapling stage when the thin, resin filled bark is easily scorched through to the cambium. After about 40 years at moist sites, and perhaps 60 years in drier localities, Douglas-fir develops a thick, fire-resistant bark, at which point Douglas-fir can resist moderate intensity surface fires. However, if moderate intensity surface fires escalate into crown fires, Douglas-fir will be killed or severely damaged as buds and fine twigs are particularly susceptible to fire. Crown fires are projected to be most likely during early to mid-seral stages of the PSMEG/JUCOD, Shawmut Family ET when stand densities are highest and when dense, low-growing Douglas-fir branches provide a pathway for fire into the overstory. At later seral stages, when trees are more widely spaced, the chance of mortal crown fires is reduced. Post-fire mortality may occur as a result of Douglas-fir beetle, wood borers, and/or western spruce budworm outbreaks, which typically follow light ground fires to moderate intensity burns.

Prescribed fire can be used to thin mature Douglas-fir forests, reduce fuel loadings, or halt the encroachment of Douglas-fir into adjacent grassland communities when mechanical thinning is logistically or monetarily prohibitive (Steinberg 2002). However, forest managers should proceed with caution as low to moderate severity controlled burns in early seral stands can quickly escalate into severe crown fires.

Douglas-fir forests provide important habitat for a variety of wildlife species (Steinberg 2002). South-facing stands of the PSMEG/JUCOD, Shawmut Family ET provide valuable winter range for mule deer, both due to thermal cover and accessibility to adjacent sagebrush and grassland communities. Rocky mountain maple and antelope bitterbrush are important browse species. A variety of songbirds, including Clark's nutcracker, black-capped and mountain chickadees, and red-breasted nuthatch, and small mammals, including red squirrels, chipmunks, mice, voles, and shrews, feed on the seeds of Douglas-fir. Blue grouse were often observed strutting about in this ecological type. Blue grouse forage on Douglas-fir buds and needles and utilize these stands for winter cover and spring breeding grounds. These forests provide little forage for domestic livestock. Common juniper is intolerant of forest fire and is generally killed or seriously damaged by moderate to severe burns (Tirmenstein 1999). Common juniper does not resprout after fire. In the case of low intensity burns, surviving individuals provide seed for regeneration. In the case of high intensity burns, where common juniper is completely obliterated in the burn area, birds and small mammals carry seeds from off-site providing a pathway for re-establishment. Common juniper cones are utilized by song-birds, including American robins and chickadees (Tirmenstein, 1999). Domestic livestock rarely feed on common juniper, which may be poisonous to domestic goats. This ET is not suited for timber harvest due to the steep, cliffy topography. In the sample stands, limber pine had overall greater basal area and trees per ha than Douglas-fir; however, Douglas-fir tended to be of a larger size class and greater height than limber pine.

Similar ecological types

Ecological Type 1

Type: Limber pine/common juniper, Lolo Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Lolo Family ET is limber pine, while the potential natural vegetation of the Shawmut Family ET is Douglas-fir.

Environmental differences: The two types are very similar environmentally. However, the Shawmut Family ET occurs at slightly cooler (avg. 1.2 ºC, 14990 degree days) sites with relatively higher site water balance (avg. -226 mm) than the Lolo Family ET (avg. 1.5 ºC, 15720 degree days, -275 mm). The soils in the Shawmut Family have relatively higher clay content (avg. 25% vs. 20%) and lower coarse fragment content (avg. 46% vs. 64%) than the Lolo Family ET.

Ecological Type 2

Type: Limber pine/common juniper, Tyzak Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Tyzak Family ET is limber pine, while the potential natural vegetation of the Shawmut Family ET is Douglas-fir.

Environmental differences: The two types differ environmentally in that soils in the Shawmut Family ET are deep Alfisols and clay-rich Mollisols, while the soils in the Tyzak Family are shallow to moderately deep Inceptisols and Mollisols.

Table 56—Summary of environmental variables for the PSMEG/JUCOD, Shawmut Family ET

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,756	2,734	2,787
Slope (%)	24	20	28
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	673	664	678
Degree days	14,990	14,830	15,230
Frost-free days	19.0	18.8	19.1
Site water balance (mm/year)	-226	-265	-188
Average annual temperature (°C)	1.2	1.2	1.3
Total annual potential evapotranspiration (mm)	566	474	615
Summer radiation (KJ)	19,980	18,100	20,750
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	46	15	66
Clay (% in particle size control section)	25	23	27
pH (in particle size control section)	7.7	7.4	8.0
Available water capacity (mm/m)	88	50	135
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	0	0	0
Exposed bedrock	0	0	0
Gravel	3	1	5
Cobble	10	0	30
Stones	4	0	5
Boulders	9	0	20
Litter	47	40	65
Wood	6	3	10
Moss and lichen	1	0	2
Basal vegetation	18	15	25
Water	0	0	0

Table 57—Constancy/cover table for common plant species occurring in the PSMEG/JUCOD, Shawmut Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	60	35	30	45
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	15	1	30
Subdominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	80	8	1	15
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	80	6	1	10
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	100	5	3	10
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	80	4	3	5
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	100	1	1	3
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	100	3	1	5
Shrubs:						
ACGL	*Acer glabrum*	Rocky Mountain maple	60	2	1	5
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	60	2	1	3
JUCOD	*Juniperus communis* var. *depressa*	common juniper	100	7	3	10
MARE11	*Mahonia repens*	Oregon grape	80	2	1	3
PUTR2	*Purshia tridentata*	antelope bitter-brush	40	1	1	1
RICEP	*Ribes cereum* var. *pedicellare*	whisky currant	40	1	1	1
ROWO	*Rosa woodsii*	woods rose	40	1	1	1
SHCA	*Shepherdia canadensis*	russet buffaloberry	100	1	1	3
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	100	3	1	5
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	80	1	1	1
AGGL	*Agoseris glauca*	pale agoseris	40	1	1	1
ANPAM	*Anemone patens* var. *multifida*	cutleaf anemone	40	1	1	1
ARCO9	*Arnica cordifolia*	heartleaf arnica	80	9	1	30
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	40	1	1	1
CARO2	*Campanula rotundifolia*	harebell	40	2	1	3
CIRSI	*Cirsium*	thistle	40	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	40	1	1	1
CYLO10	*Cymopterus longilobus*	Henderson's wavewing	100	5	1	15
EREA	*Erigeron eatonii*	Eaton's fleabane	40	1	1	1
FRSP	*Frasera speciosa*	elkweed	40	1	1	1
GABO2	*Galium boreale*	northern bedstraw	60	1	1	1
HEPA11	*Heuchera parvifolia*	small-leaved alumroot	60	1	1	1
LEFR4	*Lesquerella fremontii*	Fremont's bladderpod	40	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	40	1	1	1
PHMU3	*Phlox multiflora*	many-flowered phlox	60	1	1	1
POCO13	*Potentilla concinna*	elegant cinquefoil	80	1	1	1
SEFR3	*Senecio fremontii*	dwarf mountain ragwort	40	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	80	1	1	1
SYFO2	*Symphyotrichum foliaceum*	alpine leafybract aster	60	1	1	1
TAOF	*Taraxacum officinale*	common dandelion	40	1	1	1
Grasses:						
LEKI2	*Leucopoa kingii*	spike-fescue	100	2	1	3
POFE	*Poa fendleriana*	muttongrass	60	1	1	1
POSE	*Poa secunda*	Sandberg bluegrass	60	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	60	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 58—Stand characteristics for the PSMEG/JUCOD, Shawmut Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m^2/ha---		*-------Centimeters-------*			
PIFL2	15.6	2.3–27.6	28.2	16.0–41.7	306	104–472
PSMEG	11.0	2.3–18.4	35.8	13.5–60.2	161	15–422

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
PIFL2	32.8	13	80
PSMEG	40.9	15	113

Miscellaneous Douglas-Fir Types

Douglas-Fir/Rocky Mountain Maple, Yourame Family Ecological Type

Pseudotsuga menziesii var. *glauca/Acer glabrum*, Yourame Family Ecological Type

PSMEG/ACGL, Yourame Family ET

N = 1

The Douglas-fir/Rocky Mountain maple, Yourame Family Ecological Type occurs on the Sinks Canyon moraine within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004) and is a component of map unit 351L. This ET may also occur in other deep canyon where piedmont glacial deposits occur, including Bull Lake Creek canyon and the Whiskey Basin and Torrey Creek areas; however, it was not sampled at these sites. This ET occurred on a steep (56%), north-facing backslope in mixed dolomite and limestone colluvium over granitic glacial till. The soils were calcareous, moderately high in coarse fragments (avg. 50%), and high in clay (avg. 26%). Soils were deep, loamy-skeletal, Calcic Haplustalfs.

Potential natural vegetation of this ET is the Douglas-fir/Rocky Mountain maple habitat type (Steele and others 1983). Douglas-fir dominates the overstory and features prolific regeneration in the understory. The shrub layer is species rich and includes Rocky Mountain maple, Utah snowberry, Oregon grape, Oregon boxleaf, russet buffaloberry, common juniper, woods rose, western serviceberry, and black chokecherry. Heartleaf arnica is the most prominent herbaceous species. Other species include northern bedstraw, alpine leafybract aster, Virginia strawberry, roughfruit fairybells, and small-leaved alumroot.

Potential for timber production is generally high; however, logging opportunities may be limited on steeper sites. Rocky Mountain maple is an important browse species for domestic and wild ungulates and, in early seral stands, provides hiding and thermal cover for a variety of wildlife, including mule deer, elk, birds, and small mammals (Anderson 2001a). Please refer to the "Management Considerations" section of the PSMEG/ACGL, Redfist Family ET for more complete information on management consideration in the Douglas-fir/Rocky Mountain maple habitat type.

The PSMEG/ACGL, Yourame Family ET and the PSMEG/AGCL, Redfist Family ET are very similar in vegetation composition. However, the two types differ environmentally in that the soils of the Redfist Family ET are derived from mixed calcareous colluvium or mixed calcareous colluvium over residuum, while the soils of the Yourame Family ET are derived from mixed calcareous colluvium over granitic glacial till.

Douglas-Fir/Utah Snowberry, Typic Calciustepts Ecological Type

Pseudotsuga menziesii var. *glauca/ Symphoricarpos oreophilus* var. *utahensis*, Family Ecological Type

PSMEG/SYORU, Typic Calciustepts ET

N = 2

The Douglas-fir/Utah snowberry, Typic Calciustepts Ecological Type occurs within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004) and is a component of map unit 43L. This ET occurred on steep (avg. 61%), northwest-facing backslopes in mixed dolomite and limestone colluvium over limestone residuum. Soils were high in coarse fragments (avg. 62%) and moderately high in clay (avg. 21%). Soils were deep, loamy-skeletal, Typic Calciustepts and Inceptic Haplustalfs.

Potential natural vegetation of this ET is the Douglas-fir/Utah snowberry habitat type (Steele and others 1983). Douglas-fir and limber pine share dominance in the overstory. Douglas-fir seedlings and saplings are most prolific in the understory; however, limber pine and quaking aspen are also present. The shrub layer is generally quite sparse and always includes Utah snowberry and Oregon boxleaf, and occasionally russet buffaloberry. Heartleaf arnica, northern bedstraw, Indian milkvetch, alpine leafybract aster, and spike fescue are common herbaceous species in the typically depauperate understory.

This ET is not suitable for timber harvest due to the steep topography. Utah snowberry will resprout from basal buds on the root crown following low to moderate severity burns and often survive severe fires (Aleksoff 1999). Utah snowberry is not especially nutritious or palatable but remains an important browse species for domestic and wild ungulates, including cattle, domestic sheep, horses, pronghorn, elk, and mule deer. Lastly, the fruits of Utah snowberry provide food for grouse and magpie.

Limber Pine Series

Principal Species Descriptions

Limber Pine

Pinus flexilis James

Limber pine is a small- to medium-sized, long lived (>1000 yrs), five-needle pine (Johnson 2001a). Limber pine superficially resembles whitebark pine in its growth habit, reaching up to 15 m in height with wide-spreading upswept branches. While the geographic range of limber and whitebark pine overlap to some degree, especially in the central and northern Rocky Mountains, the two species have disparate geographic ranges to the south and west. The altitudinal range of limber and whitebark pine, while it overlaps to a small degree, is largely disparate. Where the two species co-occur geographically, whitebark pine inhabits higher elevations than limber pine.

Limber pine occurs more or less continuously near the Continental Divide and on associated mountain ranges from southeastern British Columbia and southwestern Alberta southeast to the Wind River and Owl Creek Mountains of Wyoming (Steele 1990). Outliers to this general distribution include the northern Wallowa Mountains of eastern Oregon, the Bighorn Mountains of north central Wyoming, and portions of western North Dakota, South Dakota, and Nebraska. In Wyoming, the distribution of limber pine is discontinuous south and southeast of the Wind River and Owl Creek Mountains, picking up again in northeastern Utah in the Bear River, Wasatch, and Uinta Mountains. In southeastern Wyoming, limber pine occurs in the Snowy and Laramie Ranges where it continues south into the Rocky Mountains of central Colorado and northern New Mexico. Limber pine occurs to the southwest in scattered mountain ranges across southern Utah, Arizona, Nevada, and southern California.

Limber pine occurs across a wider range of elevations than any other tree species in the central Rocky Mountains (Johnson 2001a). In the northern part of its range, including British Columbia, Alberta, and northwestern Montana, limber pine occurs near lower tree line between 1000 and 1800 m. In the central portion of its range, including eastern Oregon, central Idaho, southwestern Montana, Wyoming, and northern Utah, limber pine occurs near lower tree line between 1500 and 2900 m. The altitudinal position of limber pine shifts upward at more southerly latitudes. In southern Utah, Colorado, Nevada, New Mexico, Arizona, and California, limber pine occurs from lower to upper tree line between 2000 and 3800 m. In areas where the geographic range of limber pine overlaps with that of whitebark pine, including southeastern British Columbia, Alberta, northeastern Oregon, western Montana, central Idaho, and northwestern Wyoming, limber pine and whitebark pine sometimes co-occur at the upper elevation range of limber pine.

The majority of the geographic range of limber pine is dominated by continental climate patterns with long, cold winters; hot, dry summers; and maximum precipitation levels occurring in the late winter and spring. Exceptions are the mountains of northeastern Oregon where climate patterns have a strong maritime influence, and the southern extent of the geographic range of limber pine, including Arizona, New Mexico, southern Utah, southern Colorado, and southern California, where a summer monsoon season brings high levels of precipitation in late summer (Mock 1996). Throughout its geographic range, limber pine is commonly found on exposed, drought-stricken sites, occurring on the driest sites capable of supporting trees (Johnson 2001a). Although deep winter snow pack may occur at sites adjacent to limber pine communities, actual winter snow pack in limber pine communities is relatively low due to the redistribution of snow by wind and strong solar radiation.

Limber pine occurs across a variety of substrates but across the majority of its geographic range, it shows a strong preference for soils derived from calcareous parent materials, including limestone, dolomite, and calcareous sandstones, siltstones, and shale (Steele 1990). Limber pine may occur locally on granitic substrates and has been found in soils derived from serpentine rocks in northeastern Oregon, growing from cracks in lava in central Idaho and growing on the face of limestone and dolomite cliffs in Wyoming. Limber pine thrives on deep soils derived from colluvium and on shallow, rocky soils on summit and shoulder positions. Limber pine is intolerant of long-term soil saturation.

Limber pine is a monoecious conifer, with male cones predominately on the lower crown and female cones on the upper crown (Steele 1990). Pollenation occurs during a short period in June and July. Fertilization takes place a little over one year after pollination. Cones mature in August or September and seed dispersal occurs in September and October. Mature cones are yellow-light brown, relatively large (8-12 cm), and, unlike the cones of whitebark pine, fall from the tree intact. As previously mentioned, whitebark and limber pine have similar growth-forms, making it difficult to distinguish between the two species. Based on morphology, the differences in cone coloration, size, and ability to remain intact when mature are often the best means of distinguishing between whitebark and limber pine.

Similar to whitebark pine, limber pine is a bird-dispersed species sharing a mutualistic relationship with Clark's nutcracker. Throughout late summer and fall, Clark's nutcracker caches pine seeds for use during the winter months. An individual may transport up to 125 seeds at one time to destinations up to 22 km away from the parent tree (Vander Wall and Balda 1977). Clark's nutcracker prefers to cache seeds in areas of low snow accumulation where snows melt earlier in the winter, including south-facing sites and windward slopes. About 80% of the approximately 20,000 to 30,000 seeds per ha that a single nutcracker might cache in one season are actually retrieved and consumed, leaving the remaining 20% to be eaten by rodents or germinate (Lanner and Vander Wall 1980; Schoettle and Rochelle 2000). Seedlings will commonly germinate in clusters from Clark's nutcracker seed caches, a phenomenon that often results in clumped or multi-stem growth habit (Steele 1990). In the southern portion of its geographic range, where limber pine occurs at or above upper tree line, the krummholtz growth-form is common.

Limber pine, due to its intolerance to shade, high drought tolerance, and efficient seed dispersal by birds, is a highly successful pioneer species that is considered either seral or a topoedaphic climax species depending on the environmental conditions (Johnson 2001a). At sheltered mesic sites, limber pine is often seral to Engelmann spruce and subalpine fir at higher elevations. At lower elevations, limber pine is seral to Douglas-fir on sheltered mesic sites and is often times co-dominant with Douglas-fir on slightly xeric exposed sites (Steele 1990). At the most severe, exposed, and xeric sites, limber pine often forms all-aged, self-maintaining stands.

The fire tolerance of limber pine increases with age (Johnson 2001a). Young limber pines are highly sensitive to fire and are easily killed by even low severity burns due to thin bark. The bark at the base of older limber pine trees is often 5 cm thick, providing older individuals with protection from low severity burns. Wildfires are infrequent in limber pine communities relative to other conifers due to limited productivity and fuel accumulations associated with harsh site conditions. Fire return interval of pure limber pine stands is unpredictable and may be as high as 1000 years. In mixed stands, the fire return intervals of those species co-occurring with limber pine are relevant. Open canopied limber pine woodlands may be maintained by periodic light ground fires, which reduce undergrowth and kill more shade tolerant conifer seedlings.

The mountain pine beetle and the sugar pine tortrix (*Choristoneura lambertiana*) are the two most common insect pests of limber pine in the central and northern Rocky Mountains (Steele 1990; Hagle and others 2003). The adults and larvae of the mountain pine beetle feed on the phloem layer of the inner bark, eventually girdling the tree. Trees attacked by mountain pine beetle are inoculated with blue stain fungi, and individuals not killed directly by the beetle later succumb to the fungi. In spring, the larvae of the sugar pine tortrix mine needle sheaths and staminate flowers, often consuming up to 90% of new growth. Top kill may result from repeated defoliation.

Limber pine is susceptible to a variety of root, butt, and stem diseases, including *Phaeolus schweinitzii*, *Armillaria ostoyae*, and *Phellinus pini* (Hagle and others 2003). Lodgepole pine and limber pine dwarf mistletoes (*Arceuthobium americanum* and *A. cyanocarpum*, respectively) are common pests of limber pine. "Witches' brooms" form on infected trees. Top kill, stem cankers, and swellings are common symptoms of dwarf mistletoe infection. Trees infected by dwarf mistletoe are also more susceptible to mountain pine beetle attack. White pine blister rust is a lethal disease common to limber pine, especially in areas where gooseberries and currants, the obligate alternate host of white pine blister rust, occur. The fungus causes branch and stem cankers, which eventually girdle the branches and/or stem, causing top kill and eventually death.

Limber pine has little commercial value as timber or fuel due to slow growth and irregular form (Johnson 2001a). However, where the two species co-occur, limber pine is important in facilitating the re-establishment following disturbance of the economically important Douglas-fir by providing initial site stabilization and creating a more favorable environment for Douglas-fir seedlings in the understory. The value of limber pine as browse for large mammals is generally low, and forage is often scarce in limber pine forests due to the harsh, unproductive environment. Periodic light surface fires can be used to increase forage productivity in mature limber pine forests; however, care should be taken since even low intensity burns can damage and kill limber pine seedlings and saplings. Limber pine forests provide important winter range for mule deer and elk. The large seeds of limber pine provide highly nutritious and energy rich food for small mammals and birds. Large, dead limber pine snags are important as nesting sites for cavity nesting birds.

Limber Pine/Common Juniper, Lolo Family Ecological Type

Pinus flexilis/Juniperus communis var. *depressa*

PIFL2/JUCOD, Lolo Family ET

N = 5

Distribution

The limber pine/common juniper, Lolo Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 12L.

Environment

Aspect: East [1], east-northeast [1], northeast [1], southeast [1], south-southeast [1].

Landforms and Landscape Position: Shoulders and backslopes.

Parent Materials: Colluvium over residuum.

Parent materials are typically limestone and/or dolomite colluvium over limestone residuum.

Bedrock: Cambrian Gallatin Limestone, Ordovician Bighorn Dolomite, Mississippian Madison Limestone.

Climate: Cryic temperature regime and Udic moisture regime at elevations over approximately 2750 m elevation and/or northerly aspects. At elevations below approximately 2750 m elevation and/or on southerly aspects, soil temperature regime is Frigid and soil moisture regime is Ustic. Estimated annual precipitation ranges from 62 cm to 69 cm.

Additional environment data summaries are provided in Table 59.

Potential natural vegetation

The potential natural vegetation for this ecological type is the limber pine/common juniper or the limber pine/spike fescue habitat types (Steele and others 1983). These stands are open woodlands or savannas with limber pine forming an open canopy layer and rarely sharing dominance with Douglas-fir. Limber pine is always present and vigorously reproducing in the understory. Douglas-fir seedlings commonly occur. However, unlike the PSMEG/JUCOD, Shawmut Family ET, which occurs adjacent to the PIFL2/JUCOD, Lolo Family ET, Douglas-fir is not projected as the climax tree species. The rocky soils of the PIFL2/JUCOD, Lolo Family ET, relative to the PSMEG/JUCOD, Shawmut Family ET, are more suitable for limber pine as the projected climax species.

Common juniper is always present at low abundance in the limber pine/common juniper habitat type. Other common shrubs include mountain big sagebrush, russet buffaloberry, Utah snowberry, and antelope bitterbrush. Shrubs were absent from the one site sampled in the limber pine/spike fescue habitat type; however, mountain big sagebrush, whisky currant, and Utah snowberry are commonly associated with this habitat type, according to Steele and others (1983). The herbaceous layer is notably species rich with many species typical of adjacent sagebrush and grassland communities. In the limber pine/spike fescue habitat type, spike fescue and bluebunch wheatgrass are the predominant graminoids. Herbaceous species common to both habitat types include heartleaf arnica, timber milkvetch, hoary balsamroot, oblongleaf bluebells, woolly groundsel, flowery phlox, spearleaf stonecrop, spike fescue, and Sandberg bluegrass. Arrowleaf balsamroot, spiked ipomopsis, turpentine wavewing, and lambstongue ragwort are the most prevalent species that were found only in the limber pine/common juniper habitat type. Fremont's bladderpod, an endemic species of mustard that occurs only in Fremont County, Wyoming, was found growing on limestone outcrops in this ecological type. Summaries of species constancy/cover and stand characteristics are provided in Tables 60 and 61, respectively.

Soils

Soils in the PIFL2/JUCOD, Lolo Family ET are mostly deep with high carbonate content, a moderate degree of soil development, high coarse fragments (avg. 64%), and moderately high illuvial clay (avg. 20%). A typical soil features an A/Bk-Btk horizonation. One soil was moderately deep, with a thin A-horizon (13 cm thick), over a weak B-horizon (19 cm thick), over a sandy (83%) C-horizon (27 cm thick), over dolomite bedrock. Diagnostic soil horizons include a thick mollic epipedon (avg. 40 cm thick), and a calcic horizon (avg. 51 cm thick). One soil displayed a 68-cm thick argillic horizon. Particle size class was primarily loamy-skeletal with one soil of the sandy-skeletal class.

The soils were classified as Typic Argicryolls [1], Pachic Calcicryolls [1], Pachic Haplustolls [1], Typic Calcicryolls [1], and Typic Haplustepts [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Pachic Haplustolls

Oi—0 to 3 cm: slightly decomposed plant material; abrupt smooth boundary.

A1—3 to 15 cm: dark grayish brown (10YR 4/2) channery silty clay loam, very dark brown (10YR 2/2), moist; 12% sand; 35% clay; moderate medium subangular blocky structure, and moderate fine and medium granular structure; very friable, soft, moderately sticky, moderately plastic; common fine roots and common medium roots and common coarse roots and many very fine roots; common fine and common medium and common coarse and common very fine pores; 1% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 26% flat angular indurated 150- to 380-mm unspecified fragments; noneffervescent; neutral, pH 7.0; clear wavy boundary.

A2—15 to 31 cm: brown (7.5YR 4/2) very gravelly very gravelly silty clay loam, dark brown (7.5YR 3/2), moist; 15% sand; 32% clay; weak medium subangular blocky structure, and moderate fine granular structure; very friable, slightly hard, moderately sticky, moderately plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common very fine pores; 14% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 19% flat angular indurated 150- to 380-mm unspecified fragments and 25% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; slightly alkaline, pH 7.5; gradual wavy boundary.

AB—31 to 56 cm: brown (10YR 5/3) extremely gravelly extremely gravelly clay loam, dark brown (10YR 3/3), moist; 26% sand; 29% clay; moderate medium subangular blocky structure, and moderate fine subangular blocky structure; friable, slightly hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots and common coarse roots; common fine and common medium and common coarse pores; carbonate, finely disseminated in matrix; 13% flat angular indurated 150- to 380-mm unspecified fragments and 14% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 45% nonflat subrounded indurated 250- to 600-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.6; gradual wavy boundary.

BA—56 to 71 cm: brown (7.5YR 5/3) very gravelly very gravelly loam, dark brown (7.5YR 3/2), moist; 45% sand; 25% clay; moderate medium subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common very fine and fine roots and common medium roots; common very fine and fine and common medium and common coarse pores; carbonate, finely disseminated in matrix; 3% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 17% flat angular indurated 150- to 380-mm unspecified fragments and 39% nonflat subrounded indurated 250- to 600-mm unspecified fragments; slight effervescence; moderately alkaline, pH 8.0; clear wavy boundary.

2Bk1—71 to 92 cm: very pale brown (10YR 7/3) extremely channery loam, brown (10YR 4/3), moist; 40% sand; 22% clay; weak fine subangular blocky structure; very friable, soft, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very coarse roots; common fine and common very fine pores; carbonate, finely disseminated in matrix; 5% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 23% flat angular indurated 150- to 380-mm unspecified fragments and 42% nonflat subrounded indurated 250- to 600-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.1; clear smooth boundary.

2Bk2—92 to 110 cm: pale brown (10YR 6/3) extremely gravelly fine sandy loam, brown (10YR 5/3), moist; 55% sand; 19% clay; moderate medium subangular blocky structure, and moderate fine subangular blocky structure; friable, soft, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common very fine and fine and common medium pores; 34% patchy prominent clay films on rock fragments and 100% continuous prominent clay films on rock fragments; 10% fine prominent spherical carbonate masses in matrix and 12% fine prominent threadlike carbonate masses in matrix and 11% fine prominent threadlike carbonate masses on faces of peds; 7% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 19% flat angular indurated 150- to 380-mm unspecified fragments and 61% nonflat subrounded indurated 250- to 600-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.2; clear wavy boundary.

Ecology

The PIFL2/JUCOD, Lolo Family ET is very similar in ecology to the PIFL2/JUCOD, Tyzak Family ET (see the "Ecology" section of the latter for a detailed comparison of the two types). Limber pine is a bird-dispersed species sharing a mutualistic relationship with the Clark's nutcracker. The geographic distribution of limber pine in the study area is strongly linked with the caches of this seed harvesting bird. Limber pine is intolerant of shade and is highly drought tolerant compared to Douglas-fir. In the mid-elevation sedimentary mountains ecoregion, limber pine is seral to Douglas-fir on cooler, mesic north-facing slopes. However, on warm, south-facing, limestone and dolomite summit, shoulder, and backslope positions, limber pine forms extensive woodlands that may persist for centuries. Limber pine thrives on deep soils derived from colluvium and on shallow, rocky soils on summit and shoulder positions where other conifers are unable to survive. Pfister and others (1977) and Steele and others (1983) described the limber pine/common juniper habitat type as occurring most often on calcareous parent materials in Montana and eastern Idaho/western Wyoming, respectively, similar to the PIFL2/JUCOD, Lolo Family and PIFL2/JUCOD, Tyzak Family Ecological Types. No sign of recent wildfire was found in the sample stands of either the Tyzak or Lolo Family Ecological Types, as evidenced by the abundance of common juniper and limber pine seedling, both of which are highly intolerant of fire. Pfister and others (1977) made similar observations in sample stands of the limber pine/common juniper habitat type in Montana.

Succession

A grassland stage (A) follows directly from a stand-replacing burn, during which Clark's nutcrackers cache seeds of limber pine across the burned area, and Douglas-fir seeds carried by wind from adjacent unburned stands inundate the area (Bradley and others 1992). At moister sites, a shrub stage (B) may quickly follow the grassland stage. A fire of any intensity during the grassland or shrub stages will completely reset the successional pathway. In the absence of fire, the grassland or shrub stages are followed by a limber pine and Douglas-fir seedling/sapling stand (C), where Douglas-fir is most successful in moist microsites. On severely dry, windswept sites, Douglas-fir may not successfully reproduce and will be absent from the stand. A low intensity fire during stage (C) would maintain the seedling/sapling stand and be less favorable for Douglas-fir than limber pine, which becomes fire resistant at a younger age. A moderate severity burn at stage (C) would completely reset the successional pathway. Following the seedling/sapling stage, a mature limber pine and Douglas-fir forest (D) develops. In the continued absence of fire, a climax forest (E) of dense, mixed-age limber pine and Douglas-fir develops. Several centuries may be required to attain climax. A low to moderate intensity burn at stages (D) or (E) will result in an open-canopied, coniferous woodland of mixed age limber pine and Douglas-fir (F). Open areas created by fire are attractive caching sites for Clark's nutcracker, thus enhancing limber pine regeneration following low to moderate severity burns. Severe fires are rare in this ET due to a lack of fuels and a relatively open overstory. However, the risk of severe fires increases with stand age, and severe fires may occur in stages (D), (E), or (F), completely resetting the successional pathway.

Management considerations

The PIFL2/JUCOD, Lolo Family ET is not especially productive and is not suited for timber harvest. Also, the rocky terrain makes it difficult to access these sites with logging equipment. Low to moderate severity controlled burns may be used to reduce fuels, stimulate forage production, and maintain the open character of these stands. However, managers should take care not to allow prescribed burns to escalate into severe fires, which may result in the extirpation of common juniper and spike fescue from these sites. Common juniper and spike fescue are important in mitigating soil erosion, especially following forest fire. Also, these sites are at risk of invasion by cheatgrass following severe burns. These limber pine forests and adjacent grasslands provide important winter range for mule deer and elk. The large seeds of limber pine provide highly nutritious, energy rich food for small mammals and birds. Large, dead limber pine snags are important as nesting sites for cavity nesting birds. Spike fescue is a highly nutritious and palatable grass for domestic and wild ungulates, especially in the spring and early summer (Anderson 2005). The dense tufts of spike fescue are tolerant of moderate trampling and grazing pressure. However, spike fescue will decrease under constant heavy grazing pressure and continual trampling.

Similar ecological types

Ecological Type 1

Type: Douglas-fir/common juniper, Shawmut Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Lolo Family ET is limber pine, while the potential natural vegetation of the Shawmut Family ET is Douglas-fir.

Environmental differences: The two types are very similar environmentally. However, the Shawmut Family ET occurs at slightly cooler (avg. 1.2 ºC, 14990 degree days) sites with relatively higher site water balance (avg. -226 mm) than the Lolo Family ET (avg. 1.5 ºC, 15,720 degree days, -275 mm). The soils in the Shawmut Family have relatively high clay content (avg. 25% vs. 20%) and lower coarse fragment content (avg. 46% vs. 64%) than the Lolo Family ET.

Ecological Type 2

Type: Limber pine/common juniper, Tyzak Family ET

Floristic differences: The two types are very similar in vegetation composition.

Environmental differences: The two types differ environmentally in that soils in the Lolo Family ET are mostly deep Mollisols with thick (avg. 40 cm thick) mollic epipedons, while the soils in the Tyzak Family are shallow to moderately deep Inceptisols and Mollisols with relatively thin (avg. 22 cm thick) mollic epipedons.

Table 59—Summary of environmental variables for the PIFL2/JUCOD, Lolo Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,718	2,652	2,859
Slope (%)	21	16	32
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	651	619	694
Degree days	15,720	14,360	16,480
Frost-free days	19.3	18.7	19.7
Site water balance (mm/year)	-275	-313	-231
Average annual temperature (°C)	1.5	1.0	1.8
Total annual potential evapotranspiration (mm)	590	516	642
Summer radiation (KJ)	20,090	19,400	20,620
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	64	47	79
Clay (% in particle size control section)	20	9	27
pH (in particle size control section)	7.8	7.7	8.0
Available water capacity (mm/m)	55	34	75
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	4	1	10
Exposed bedrock	3	0	10
Gravel	13	3	35
Cobble	10	5	15
Stones	9	5	15
Boulders	2	0	3
Litter	30	10	65
Wood	7	4	10
Moss and lichen	1	0	2
Basal vegetation	20	10	30
Water	0	0	0

Table 60—Constancy/cover table for common plant species occurring in the PIFL2/JUCOD, Lolo Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	100	18	5	25
Subdominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	50	8	5	10
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	100	4	3	5
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	100	2	1	5
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	50	2	1	3
Shrubs:						
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	75	17	5	30
JUCOD	*Juniperus communis* var. *depressa*	common juniper	100	4	3	5
MARE11	*Mahonia repens*	Oregon grape	75	1	1	1
PUTR2	*Purshia tridentata*	antelope bitter-brush	75	3	1	5
SHCA	*Shepherdia canadensis*	russet buffaloberry	100	4	1	5
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	100	2	1	3
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	75	1	1	1
AGGL	*Agoseris glauca*	pale agoseris	50	1	1	1
ANMA	*Anaphalis margaritacea*	common pearly-everlasting	50	1	1	1
ARCO9	*Arnica cordifolia*	heartleaf arnica	50	1	1	1
ASMI9	*Astragalus miser*	timber milkvetch	50	2	1	3
ASTER	*Aster*	aster	50	1	1	1
BAIN	*Balsamorhiza incana*	hoary balsamroot	50	3	1	5
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	75	3	1	5
CASTI2	*Castilleja*	Indian-paintbrush	50	1	1	1
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	50	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	50	1	1	1
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	50	3	3	3
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	50	1	1	1
GABO2	*Galium boreale*	northern bedstraw	75	6	1	15
IPSP	*Ipomopsis spicata*	spiked ipomopsis	75	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	75	1	1	1
PACA15	*Packera cana*	woolly groundsel	50	1	1	1
PEHU	*Penstemon humilis*	low beardtongue	50	1	1	1
PHMU3	*Phlox multiflora*	many-flowered phlox	75	2	1	3
POOV2	*Potentilla ovina*	sheep cinquefoil	50	1	1	1
SEIN2	*Senecio integerrimus*	lambstongue ragwort	50	2	1	3
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	75	1	1	1
ZIVEG	*Zigadenus venenosus* var. *gramineus*	grassy deathcamas	50	1	1	1
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	50	1	1	1
FEID	*Festuca idahoensis*	Idaho fescue	50	2	1	3
LEKI2	*Leucopoa kingii*	spike-fescue	100	4	3	5
POSE	*Poa secunda*	Sandberg bluegrass	100	2	1	5
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	50	3	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 61—Stand characteristics for the PIFL2/JUCOD, Lolo Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m²/ha---		*-------Centimeters-------*			
PIFL2	13.8	9.2–16.1	30.7	16.7–58.4	257	52–366
PSMEG	2.3	—	42.7	—	15	—

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
PIFL2	32.3	11	95
PSMEG	41.5	13	90

Limber Pine/Common Juniper, Tyzak Family Ecological Type

Pinus flexilis/Juniperus communis var. *depressa*, Tyzak Family Ecological Type

PIFL2/JUCOD, Tyzak Family ET

N = 6

Distribution

The limber pine/common juniper, Tyzak Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 12L.

Environment

Aspect: East [1], east-southeast [2], south [1], south-southwest [1], southwest [1].

Landforms and Landscape Position: Shoulders and Summits.

Parent Materials: Residuum, colluvium over residuum.

Bedrock: Cambrian Gallatin Limestone, Ordovician Bighorn Dolomite, Mississippian Madison Limestone.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 55 to 66 cm.

Additional environment data summaries are provided in Table 62.

Potential natural vegetation

The potential natural vegetation of this ecological type is the limber pine/common juniper habitat type (Steele and others 1983). Limber pine forms an open canopy layer, sometimes sharing dominance with Douglas-fir. Limber pine occurs widely spaced, and these stands often resemble more of a woodland than a forest. Limber pine is always present and vigorously reproducing in the understory. Douglas-fir seedlings commonly occur in this ET. Small stands of Douglas-fir occasionally occur in pockets of deep soil near this ET. Douglas-fir in these stands can be quite large and old as they are protected from fire by the limestone and dolomite rock outcrops typical of these sites. However, unlike the PSMEG/JUCOD, Shawmut Family ET, which may occur adjacent to the PIFL2/JUCOD, Tyzak Family ET, Douglas-fir is not projected as the climax tree species at these sites. The shallow, rocky soils of the PIFL2/JUCOD, Tyzak Family ET, relative to the PSMEG/JUCOD, Shawmut Family ET, are more suitable for limber pine as the projected climax dominant species.

The shrub layer is quite diverse and often resembles nearby sagebrush communities. Common juniper is always present, usually as widely scattered individuals. Mountain big sagebrush, antelope bitterbrush, Utah snowberry, and whisky currant are shrub species reflective of the open canopy layer and intense solar radiation experienced by this type. Rockspirea may also be found in this ecological type growing out of cracks in the limestone outcrops. Russet buffaloberry may occur at relatively high abundance at cooler, high elevation sites.

The herbaceous layer, like the shrub layer, is very diverse and quite similar to adjacent sagebrush and grassland communities. In the spring and early summer, the striking yellow flowers of hoary and/or arrowleaf balsamroot, and the bursting white flowers of many-flowered phlox are always present. Less noticeable yet common forbs include turpentine wavewing, wooly groundsel, sulphur-flower buckwheat, oblongleaf bluebells, low beardtongue, and sheep cinquefoil. Bluebunch wheatgrass, spike fescue, and Sandberg bluegrass are typical grasses. Obtuse sedge, common in this ecological type, is a low growing, inconspicuous sedge with solitary stems arising linearly along creeping rhizomes. Summaries of species constancy/cover and stand characteristics are provided in Tables 63 and 64, respectively.

Soils

Soils in the PIFL2/JUCOD, Tyzak Family ET were shallow to moderately deep and calcareous, with a low degree of soil development, moderate to high coarse fragments (48-81%, avg. 63%), and variable clay (8-33%, avg. 20%). Accumulations of clay minerals were the result of in situ weathering rather than pedogenic transport to subsurface horizons. A typical soil featured an A/Bk/R horizonation. Mollisols featured a mollic epipedon (avg. 22 cm thick), while Inceptisols featured a thin ochric epipedon (avg. 7 cm thick). Diagnostic subsurface horizons included a calcic horizon (avg. 35 cm thick) over shallow to moderately deep lithic contact (avg. 60-cm depth). Particle size class was loamy-skeletal. The soils were Lithic Calciustolls [3], and Typic Calciustepts [3].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Lithic Calciustolls

<u>A1—0 to 8 cm</u>: brown (10YR 4/3) very gravelly loam, very dark grayish brown (10YR 3/2), moist; 43% sand; 22% clay; moderate medium subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; many fine roots and common medium roots and common coarse roots and many very fine roots; many fine and common medium and common coarse and many very fine pores; 11% 251- to 600-mm unspecified fragments and 16% 76- to 250-mm unspecified fragments and 24% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly alkaline, pH 7.4; clear wavy boundary.

<u>A2—8 to 27 cm</u>: brown (10YR 5/3) very cobbly fine sandy loam, dark brown (10YR 3/3), moist; 71% sand; 11% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and many very fine roots; common fine and common medium and common coarse and many very fine pores; distinct carbonate coats on bottom surfaces of rock fragments; 2% 251- to 600-mm unspecified fragments and 27% 2-to 75-mm unspecified fragments and 30% 76- to 250-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly alkaline, pH 7.6; clear wavy boundary.

<u>Bk—27 to 45 cm</u>: pale brown (10YR 6/3) very cobbly loamy fine sand, brown (10YR 5/3), moist; 78% sand; 8% clay; weak very fine subangular blocky structure, and moderate fine granular structure; very friable, soft, nonsticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; patchy distinct carbonate coats on rock fragments; 10% fine carbonate nodules in matrix; 22% 76- to 250-mm unspecified fragments and 26% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.1; very abrupt smooth boundary.

<u>R—45 cm</u>: limestone bedrock.

Ecology

The limber pine/common juniper, Tyzak Family ET is very similar in ecology to the limber pine/common juniper, Lolo Family ET (see the ”Ecology” section of the latter for a detailed description of the ecology of limber pine/common juniper woodlands). The primary difference between the two Ecological Types is that the soils in the Tyzak Family ET were shallow to moderately deep to bedrock with a thin Mollic epipedon, while the soils of the Lolo Family ET were typically deep with a thick Mollic epipedon. The difference in soils is a reflection of the different parent materials and slope positions inhabited by the two Ecological Types, with the shallow to moderately deep soils of the Tyzak Family ET occurring on shoulders and summits in residual limestone and dolomite soils, and the deeper soils of the Lolo Family ET occurring primarily on backslopes in soils derived from mixed limestone colluvium. The two types are nearly identical in vegetation composition, with the exception that the Tyzak Family ET typically features smaller, more widely spaced limber pine than the Lolo Family ET. Environmentally, the difference in slope position and parent material is more distinct. However, the line separating the two Ecological Types is slightly blurred as the result of a continuum in soil development and depth to bedrock between the two types.

Succession

A grassland stage (A) follows directly from a stand-replacing burn, during which Clark’s nutcrackers cache seeds of limber pine across the burned area and Douglas-fir seeds carried by wind from adjacent unburned stands inundate the area (Bradley and others 1992). At more moist sites, a shrub stage (B) may quickly follow the grassland stage. A fire of any intensity during the grassland or shrub stages will completely reset the successional pathway. In the absence of fire, the grassland or shrub stages are followed by a limber pine and Douglas-fir seedling/sapling stand (C), where Douglas-fir is most successful in moist microsites On severely dry, windswept sites, Douglas-fir may not successfully reproduce and will be absent from the stand. A low intensity fire during stage (C) would maintain the seedling/sapling stand and be less favorable for Douglas-fir than limber pine, which becomes fire resistant at a younger age. A moderate severity burn at stage (C) would completely reset the successional pathway. Following the seedling/sapling stage, a mature limber pine and Douglas-fir forest (D) develops. In the continued absence of fire, a climax forest (E) of dense, mixed-age limber pine and Douglas-fir develops. Several centuries may be required to attain climax. A low to moderate intensity burn at stages (D) or (E) will result in an open-canopied, coniferous woodland of mixed-age limber pine and Douglas-fir (F). Open areas created by fire are attractive caching sites for Clark’s nutcracker, thus enhancing limber pine regeneration following low to moderate severity burns. Severe fires are rare in this ET due to a lack of fuels and a relatively open overstory. However, the risk of severe fires increases with stand age, and severe fires may occur in stages (D), (E), or (F), completely resetting the successional pathway.

Management considerations

The PIFL2/JUCOD, Tyzak Family ET is not especially productive and is not suited for timber harvest. Also, the rocky terrain makes it difficult to access these sites with logging equipment. Low to moderate severity controlled burns may be used to reduce fuels, stimulate forage production, and maintain the open character of these stands. However, managers should take care not to allow prescribed burns to escalate into severe fires, which may result in the extirpation of common juniper and spike fescue from these sites. Common juniper and spike fescue are important in mitigating soil erosion, especially following forest fire. Also, these sites are at risk of invasion by cheatgrass following severe burns. These limber pine forests and adjacent grasslands provide important winter range for mule deer and elk. The large seeds of limber pine provide highly nutritious, energy rich food for small mammals and birds. Large, dead limber pine snags are important as nesting sites for cavity nesting birds.

Similar ecological types

Ecological Type 1

Type: Douglas-fir/common juniper, Shawmut Family ET

Floristic differences: The two types differ in that the potential natural vegetation of the Tyzak Family ET is limber pine, while the potential natural vegetation of the Shawmut Family ET is Douglas-fir.

Environmental differences: The two types differ in that the soils of the Tyzak Family ET are typically shallow to moderately deep Inceptisols and Mollisols, whereas the soils of the Shawmut Family ET are typically Alfisols and clay-rich Mollisols. Also, the Shawmut Family ET occurs at slightly cooler (avg. 1.2 ºC, 14990 degree days) sites with relatively higher site water balance (avg. -226 mm) than the Tyzak Family ET (avg. 1.8 ºC, 16490 degree days, -339 mm). The soils in the Shawmut Family have relatively high clay content (avg. 25% vs. 20%) and lower coarse fragment content (avg. 46% vs. 63%) than the Tyzak Family ET.

Ecological Type 2

Type: Limber pine/common juniper, Lolo Family ET

Floristic differences: The two types are very similar in vegetation composition.

Environmental differences: The two types differ environmentally in that soils in the Lolo Family ET are mostly deep Mollisols with thick (avg. 40 cm thick) mollic epipedons, while the soils in the Tyzak Family are shallow to moderately deep Inceptisols and Mollisols with relatively thin (avg. 22 cm thick) mollic epipedons.

Table 62—Summary of environmental variables for the PIFL2/JUCOD, Tyzak Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,620	2,408	2,719
Slope (%)	23	2	40
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	623	545	657
Degree days	16,490	15,560	19,040
Frost-free days	19.7	19.2	21.0
Site water balance (mm/year)	-339	-434	-284
Average annual temperature (°C)	1.8	1.5	2.8
Total annual potential evapotranspiration (mm)	650	576	729
Summer radiation (KJ)	20,750	20,020	22,030
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	63	48	81
Clay (% in particle size control section)	20	8	33
pH (in particle size control section)	8.1	7.8	8.3
Available water capacity (mm/m)	33	19	51
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	7	0	20
Exposed bedrock	7	0	15
Gravel	7	1	20
Cobble	13	1	40
Stones	4	2	10
Boulders	3	1	10
Litter	22	5	45
Wood	2	2	2
Moss and lichen	0	0	0
Basal vegetation	34	15	60
Water	0	0	0

Table 63—Constancy/cover table for common plant species occurring in the PIFL2/JUCOD, Tyzak Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Dominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	100	18	3	35
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	50	7	1	15
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	83	3	1	5
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	83	2	1	5
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	50	1	1	1
Shrubs:						
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	83	4	1	10
JUCOD	*Juniperus communis* var. *depressa*	common juniper	83	4	1	5
MARE11	*Mahonia repens*	Oregon grape	50	1	1	1
PUTR2	*Purshia tridentata*	antelope bitter-brush	67	4	1	5
RICEP	*Ribes cereum* var. *pedicellare*	whisky currant	67	1	1	1
ROWO	*Rosa woodsii*	woods rose	50	1	1	1
SHCA	*Shepherdia canadensis*	russet buffaloberry	67	4	1	10
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	83	2	1	3
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	67	1	1	1
ASMI9	*Astragalus miser*	timber milkvetch	67	3	1	8
BAIN	*Balsamorhiza incana*	hoary balsamroot	67	7	1	20
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	67	2	1	5
CAPA25	*Castilleja pallescens*	palish Indian-paintbrush	50	1	1	1
CIRSI	*Cirsium*	thistle	50	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	50	1	1	1
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	83	2	1	3
ERAS2	*Erysimum asperum*	sanddune wallflower	50	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	50	2	1	3
EROV	*Eriogonum ovalifolium*	cushion buckwheat	50	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	67	1	1	1
LILE3	*Linum lewisii*	prairie flax	50	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	67	1	1	1
PACA15	*Packera cana*	woolly groundsel	67	1	1	1
PEHU	*Penstemon humilis*	low beardtongue	67	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	50	2	1	3
PHMU3	*Phlox multiflora*	many-flowered phlox	83	4	3	8
POOV2	*Potentilla ovina*	sheep cinquefoil	67	2	1	3
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	67	1	1	1
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	67	2	1	3
LEKI2	*Leucopoa kingii*	spike-fescue	83	4	3	10
POSE	*Poa secunda*	Sandberg bluegrass	67	3	1	5
Graminoids:						
CAOB4	*Carex obtusata*	obtuse sedge	67	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 64—Stand characteristics for the PIFL2/JUCOD, Tyzak Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m²/ha---		*-------Centimeters-------*			
PIFL2	8.7	6.9–11.5	26.4	13.7–41.4	227	82–464
PSMEG	6.9	2.3–13.8	37.6	16.5–86.4	124	15–326

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PIFL2	26.7	8	62
PSMEG	36.1	12	85

Limber Pine/Spike Fescue, Saddlehorse Family Ecological Type

Pinus flexilis/Leucopoa kingii, Saddlehorse Family Ecological Type

PIFL2/LEKI2, Saddlehorse Family ET

N = 3

Distribution

The limber pine/spike fescue, Saddlehorse Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Red Creek, northwest to Bald Mountains. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 15L.

Environment

Aspect: South-southwest [2], southwest [1].

Landforms and Landscape Position: Upper backslopes on landslide deposits.

Parent Materials: Mixed Bighorn Dolomite and Gallatin Limestone colluvium.

Bedrock: Cambrian Gros Ventre Shale, Cambrian Gallatin Limestone.

This ecological type occurs on steep backslopes near the contact between the Gros Ventre and Gallatin Formations. The type of bedrock at a given site will vary depending on the slope position relative to the particular geologic stratigraphy at the site.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 62 to 65 cm.

Additional environment data summaries are provided in Table 65.

Potential natural vegetation

The potential natural vegetation of this ecological type is the limber pine/spike fescue habitat type (Steele and others 1983). These stands are open woodlands or savannas, with large, widely spaced limber pine, robust mountain big sagebrush, and antelope bitterbrush. Whisky currant and Utah snowberry occur as large solitary individuals growing amongst the sagebrush. Small aspen clones commonly occur scattered throughout this ecological type. Spike fescue, although the dominant grass species, typically occurs at low abundance scattered throughout the understory. Bluebunch wheatgrass and Sandberg bluegrass often codominate with spike fescue. The forb layer resembles that of nearby mountain big sagebrush/bluebunch wheatgrass communities. Common forbs include arrowleaf balsamroot, sanddune wallflower, sulphur-flower buckwheat, oblongleaf bluebells, woolly groundsel, many-flowerd phlox, and lambstongue ragwort. Summaries of species constancy/cover and stand characteristics are provided in Tables 66 and 67, respectively.

Soils

Soils in the PIFL2/LEKI2, Saddlehorse Family ET were deep and calcareous with a low to moderate degree of soil development, moderate coarse fragments (avg. 60%), and moderate clay (avg. 21%). Soils typically featured an A-Bk horizonation. Diagnostic soil horizons include a thick mollic epipedon (avg. 62 cm thick) and a calcic horizon (avg. 57 cm thick). One soil was lacking a calcic horizon, and featured instead a 64-cm thick argillic horizon over an extremely gravelly C-horizon (17+ cm thick). Particle size class was loamy-skeletal. The soils were Typic Calciustolls [1], Pachic Calciustolls [1], and Pachic Argiustolls [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Typic Calciustolls

A1—0 to 4 cm: dark grayish brown (10YR 4/2) medium gravelly very fine sandy loam, very dark brown (10YR 2/2), moist; 58% sand; 17% clay; weak fine subangular blocky structure, and moderate fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common medium and common very fine pores; 17% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.6; clear wavy boundary.

A2—4 to 15 cm: brown (10YR 4/3) medium gravelly sandy clay loam, very dark grayish brown (10YR 3/2), moist; 56% sand; 20% clay; weak fine subangular blocky structure, and moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many medium roots and common coarse roots and common very coarse roots and common very fine roots; common fine and many medium and common coarse and common very coarse and common very fine pores; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 24% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.5; clear wavy boundary.

BA—15 to 37 cm: brown (10YR 4/3) coarse gravelly loam, dark brown (10YR 3/3), moist; 50% sand; 21% clay; weak medium subangular blocky structure, and moderate fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots and common very coarse roots; common very fine and fine and common medium and common coarse and common very coarse pores; 25% patchy distinct carbonate coats on bottom surfaces of rock fragments; 10% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 21% nonflat subrounded indurated 2- to 75-mm unspecified fragments; slight effervescence; slightly alkaline, pH 7.6; gradual irregular boundary.

Bk1—37 to 61 cm: brown (10YR 5/3) very cobbly loam, brown (10YR 4/3), moist; 46% sand; 23% clay; moderate fine subangular blocky structure, and moderate very fine subangular blocky structure; friable, moderately hard, moderately sticky, slightly plastic; common very fine and fine roots and common medium roots and common coarse roots; common very fine and fine and common medium and common coarse pores; 40% patchy distinct carbonate coats on rock fragments; 13% fine faint carbonate masses in matrix; 16% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 20% nonflat subrounded indurated 2- to 75-mm unspecified fragments; strong effervescence; moderately alkaline, pH 8.1; clear wavy boundary.

2Bk2—61 to 76 cm: pale brown (10YR 6/3) very gravelly sandy clay loam, brown (10YR 4/3), moist; 62% sand; 20% clay; moderate fine subangular blocky structure, and moderate very fine subangular blocky structure; friable, hard, slightly sticky, moderately plastic; common medium roots and common coarse roots and common very coarse roots and common very fine roots; common medium and common coarse and common very coarse and common very fine pores; 50% patchy distinct carbonate coats on rock fragments; 13% fine faint carbonate masses in matrix; 12% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 30% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.2; clear wavy boundary.

2Bk3—76 to 103 cm: white (10YR 8/1) extremely gravelly sandy clay loam, light yellowish brown (2.5Y 6/3), moist; 57% sand; 21% clay; moderate fine subangular blocky structure, and moderate very fine subangular blocky structure; friable, hard, slightly sticky, slightly plastic; common fine roots and common coarse roots; common fine and common coarse and common very fine pores; 65% patchy distinct carbonate coats on rock fragments; 8% fine faint carbonate masses in matrix and 5% medium distinct carbonate nodules in matrix; 19% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 46% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; moderately alkaline, pH 8.2.

Ecology

In the mid-elevation sedimentary mountains ecoregion, forested vegetation is generally limited to limestone, dolomite, and sandstone slopes. The PIFL2/LEKI, Saddlehorse Family ET is unique in that it represents forested vegetation that occurs on shale and siltstone slopes, typically below Bighorn Dolomite outcrops. The soils were highly calcareous and derived from deep, mixed limestone and dolomite colluvium. South-facing Gros Ventre slopes lacking Bighorn Dolomite outcrops upslope never featured forested vegetation, suggesting that the occurrence of this ET on Gros Ventre Shale slopes is somehow related to the dolomite in the soil.

The occurrence of forested vegetation on Gros Ventre slopes with heavy dolomite influence may be related to the availability of phosophorus in calcareous soils and the mediating effects of magnesium present in the dolomite. Phosphorus is a key nutrient often limiting productivity in terrestrial ecosystems and is also one of the few elements that must be supplied almost entirely from the parent material of a soil (Walker and Syers 1976). Calcium carbonate controls the availability of phosphorus in soils by sequestering phosphorus in precipitates of calcium-phosphate (Lajtha and Schlesinger 1988). Dolomite is a calcium-magnesium carbonate ($CaMg(CO3)_2$) formed by a process termed dolotimization, where magnesium rich solutions pass through carbonate rich sediments altering its chemical composition. Magnesium has the opposite effect on phosphates than calcium, leading to higher available phosphates in soils where magnesium is present, such as those weathered from dolomite (Shariatmadan and Mermut 1999). Limber pine communities may be able to establish on Gros Ventre slopes below Bighorn Dolomite outcrops due to the higher available phosphorus provided by the dolomitic soils.

Succession

A grassland stage (A) follows directly from a stand-replacing burn, during which Clark's nutcrackers cache seeds of limber pine across the burned area and Douglas-fir seeds carried by wind from adjacent unburned stands inundate the area (Bradley and others 1992). A mountain big sagebrush stage with scattered limber pine and Douglas-fir seedlings (B) gradually follows the grassland stage. A fire of any intensity during the grassland or sagebrush stages will completely reset the successional pathway. In the absence of fire, the grassland or sagebrush stages are followed by a limber pine and Douglas-fir sapling stand (C), where Douglas-fir is most successful in moist microsites. On severely dry, windswept sites, Douglas-fir may not successfully reproduce and will be absent from the stand. A low intensity fire during stage (C) would maintain the sapling stand and be less favorable for Douglas-fir than limber pine, which becomes fire resistant at a younger age. A moderate severity burn at stage (C) would completely reset the successional pathway. Following the sapling stage, a mature limber pine and Douglas-fir forest (D) develops. In the continued absence of fire, a climax forest (E) of closed, mixed-age limber pine and Douglas-fir develops. Several centuries may be required to attain climax. A low to moderate intensity burn at stages (D) or (E) will result in an open-canopied, coniferous woodland of mixed age limber pine and Douglas-fir (F). Open areas created by fire are attractive caching sites for Clark's nutcracker, thus enhancing limber pine regeneration following low to moderate severity burns. Severe fires are more common in this ET than other limber pine Ecological Types due to a high concentration of fuels and adjacency to mountain big sagebrush communities. The risk of severe fires increases with stand age, and severe fires are most common in stages (D), (E), or (F), completely resetting the successional pathway.

Management considerations

The PIFL2/LEKI, Saddlehorse Family ET is not suited for timber harvest. This ET provides excellent foraging opportunities for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are also close at hand. Blue grouse are commonly found in this ecological type. Low to moderate severity controlled burns may be used to reduce fuels, stimulate forage production, and maintain the open character of these stands. However, managers should take care not to allow prescribed burns to escalate into severe fires, which may result in the extirpation of mountain big sagebrush, antelope bitterbrush, and spike fescue from these sites. Also, these sites are at risk of invasion by cheatgrass following severe burns.

Mountain big sagebrush is killed by even light severity fires and will not resprout from the root crown if the above ground portion of the plant is completely killed (Welch 2005). Antelope bitterbrush is highly susceptible to fire kill and is often killed by summer or fall fire (Zlatnik 1999a). Antelope bitterbrush in some regions may sprout after light severity spring fire; however, the resprouting ability of antelope bitterbrush is dependent on a number of factors, including fire severity, season, plant genetics, carbohydrate stores, and age. Fire generally favors bluebunch wheatgrass and stimulates flowering, seed, and tiller production (Zlatnik 1999b). Seasonality of fires strongly affects mortality. Bluebunch wheatgrass receives the least damage when burned while dormant in fall, winter, or early spring and the most damage when burned while actively growing in the late spring and summer. Soil moisture status prior to and following fires also affects mortality and recovery time. Recovery following fires is generally rapid (one-five years); however, a lack of adequate soil moisture following a burn can slow recovery and increase mortality. Low soil moisture prior to burning increases fire severity. Spike fescue is tolerant of periodic, low to moderate intensity fires, which typically kills the above ground portion of the plant. Spike fescue is considered an "increaser" following low to moderate intensity fires. High intensity fires may kill underground rhizomes, in which case post-fire regeneration is from off-site seed sources

Bluebunch wheatgrass is moderately tolerant of grazing and is considered a grazing "decreaser" since heavy grazing can result in lower root and stem carbohydrate reserves, a condition leading to decreased vigor or mortality. Bluebunch wheatgrass is most sensitive to grazing during its active growth period in spring and early summer. Antelope bitterbrush is a highly palatable, nutrient- and protein-rich browse species utilized by a variety of wild and domestic ungulates (Zlatnik 1999a). Antelope bitterbrush is moderately browse tolerant and is considered a "decreaser" under heavy browsing pressure.

Similar ecological types

Ecological Type 1

Type: NONE

Table 65—Summary of environmental variables for the PIFL2/LEKI2, Saddlehorse Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,651	2,600	2,694
Slope (%)	41	30	51
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	636	622	652
Degree days	16,090	15,570	16,640
Frost-free days	19.5	19.3	19.7
Site water balance (mm/year)	-312	-343	-295
Average annual temperature (°C)	1.7	1.5	1.9
Total annual potential evapotranspiration (mm)	661	633	681
Summer radiation (KJ)	20,740	20,570	20,830
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	60	48	68
Clay (% in particle size control section)	21	15	28
pH (in particle size control section)	7.9	7.6	8.0
Available water capacity (mm/m)	72	56	89
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	8	2	15
Exposed bedrock	0	0	0
Gravel	13	5	25
Cobble	5	2	10
Stones	4	1	5
Boulders	7	2	10
Litter	23	15	35
Wood	3	2	3
Moss and lichen	1	0	2
Basal vegetation	37	20	50
Water	0	0	0

Table 66—Constancy/cover table for common plant species occurring in the PIFL2/LEKI2, Saddlehorse Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIFL2	*Pinus flexilis*	limber pine	100	23	15	35
Saplings:						
PIFL2	*Pinus flexilis*	limber pine	100	6	1	15
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	100	2	1	3
Shrubs:						
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	32	25	35
PUTR2	*Purshia tridentata*	antelope bitter-brush	100	5	1	10
RICEP	*Ribes cereum* var. *pedicellare*	whisky currant	100	2	1	5
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	67	4	3	5
Forbs:						
AGGL	*Agoseris glauca*	pale agoseris	67	2	1	3
ASMI9	*Astragalus miser*	timber milkvetch	67	2	1	3
ASTRA	*Astragalus*	milk-vetch	67	1	1	1
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	67	8	1	15
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	100	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	67	1	1	1
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	67	2	1	3
ERAS2	*Erysimum asperum*	sanddune wallflower	100	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	100	1	1	1
IPSP	*Ipomopsis spicata*	spiked ipomopsis	67	1	1	1
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	67	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	100	2	1	3
OXSE	*Oxytropis sericea*	white locoweed	67	1	1	1
PACA15	*Packera cana*	woolly groundsel	100	1	1	1
PEHU	*Penstemon humilis*	low beardtongue	67	1	1	1
PHMU3	*Phlox multiflora*	many-flowered phlox	100	2	1	3
SEIN2	*Senecio integerrimus*	lambstongue ragwort	100	2	1	3
TAOF	*Taraxacum officinale*	common dandelion	67	1	1	1
VIOLA	*Viola*	violet	67	2	1	3
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	4	3	5
FEID	*Festuca idahoensis*	Idaho fescue	67	1	1	1
LEKI2	*Leucopoa kingii*	spike-fescue	100	5	3	10
POSE	*Poa secunda*	Sandberg bluegrass	100	7	1	10

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 67—Stand characteristics for the PIFL2/LEKI2, Saddlehorse Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
PIFL2	11.5	6.9–13.8	29.0	13.7–47.8	237	188–279
PSMEG	4.6	—	40.1	29.7–50.5	44	—

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
PIFL2	31.2	9	70
PSMEG	50.5	20	89

Miscellaneous Limber Pine Types

Limber Pine/Common Juniper, Como Family Ecological Type

Pinus flexilis/Juniperus communis var. *depressa*

PIFL2/JUCOD, Como Family ET

N = 1

The limber pine/common juniper, Como Family Ecological Type occurs along the southern WRR within the granitic subalpine zone of Chapman and others (2004). This ET occurs between Frye Lake and Meyer Lookout and just to the west of the South Pass Granite-Greenstone Belt. It is a component of map unit 317L.

This ET occurs on summits, shoulders, and backslopes of steep outcrops of Louis Lake Granodiorite. Elevation ranges between 2,600 and 2,900 m. This ET was observed on slope gradients between 25 and 60%. The average annual precipitation ranges between 59 and 65 cm. Parent materials were granodiorite colluvium over granodiorite residuum. Soils were generally shallow to moderately deep, sandy skeletal Typic Eutrocryepts. Soils were high in gravels and boulders.

Potential natural vegetation of this ET is the limber pine/common juniper habitat type (Steele and others 1983). Within the higher elevation range of this ET, potential natural vegetation may be whitebark pine/common juniper habitat type common juniper phase. Limber pine co-occurs with whitebark and lodgepole pine in the overstory forming an open tree canopy (15–20%). Limber pine is present and vigorously regenerating in the understory canopy layer. Whitebark and lodgepole pine seedlings often occur as scattered individuals. At extremely bouldery sites, quaking aspen is often present in the understory.

Common juniper and russet buffaloberry are the most common shrub species present. Utah snowberry, antelope bitterbrush, and mountain big sagebrush are shrub species indicative of the warm, sunny conditions typical of this ecological type. The PIFL2/JUCOD, Como Family ET is similar in vegetation composition to the PIFL2/JUCOD, Lolo and PIFL2/JUCOD, Tyzak Family Ecological Types. However, the Como Family ET soils are formed from granitic parent materials, while the soils in the Lolo and Tyzak Family Ecological Types are formed from calcareous parent materials.

Lodgepole Pine Series

Principal Species Descriptions

Lodgepole Pine

Pinus contorta var. *latifolia* Dougl. ex Loud. Engelm. Ex S. Wats.

Lodgepole pine has been classified into four geographically distinct varieties:*P. contorta* var. *contorta* from the Pacific Coast, *P. contorta* var. *bolanderi* from Mendocino County California, *P. contorta* var. *murrayana* from the Sierra Nevada Mountains, and *P. contorta* var. *latifolia* from the Rocky Mountains (Lotan and Critchfield 1990). The remainder of the discussion will focus on the latter variety, *P. contorta* var. *latifolia*.

Lodgepole pine is a widely distributed tree species in the Rocky Mountain west, occurring in the north from southern Yukon Territory, southwestern Northwest Territory, and the inland mountains of southeastern Alaska, south through inland British Columbia and western Alberta (Kral 1993). In the south, lodgepole pine occurs in eastern Washington and Oregon, Idaho, and western Montana, south through northwestern Wyoming, northern Utah, and central Colorado. Disjunct populations occur in southwestern Saskatchewan, the Bighorn Mountains of central Wyoming, and the Black Hills in western South Dakota.

Lodgepole pine has a broad range of environmental tolerance, occurring in lower montane, subalpine, and timberline forests, on seasonally saturated soils to extremely droughty sites (Anderson 2003). A lack of adequate precipitation limits lodgepole pine at lower elevations, while a short growing season sets the upper elevation limit. Lodgepole pine typically grows where precipitation is greater than 460 mm but may survive at sites receiving as little as 250 mm. The elevation range of lodgepole pine is inversely related to latitude. For instance, in Idaho and Montana, the elevation range of lodgepole pine is 1670 to 2,380 m and 1,370 and 2,700 m, respectively. At the southern end of its geographic range, in Colorado and Utah, the elevation range of lodgepole pine is 2,100 to 3,500 m and 1,820 to 3,350 m, respectively. In Wyoming, lodgepole pine occurs between 1820 and 3200 m. Lodgepole pine occurs on nearly every substrate type and on soils ranging from deep and well developed to shallow, extremely rocky, and poorly developed. Lodgepole pine is most productive on coarse-grained, non-calcareous substrates; however, it can be found growing on medium- to fine-grained, calcareous substrates as well (Anderson 2003). Lodgepole pine is tolerant of nutrient poor soils derived from rhyolite, tuff, pumice, and sandstone and is intolerant of saline soils and high concentrations of heavy metals, including zinc, copper, cadmium, and mercury.

Lodgepole pine is intolerant of shade, moderately to highly frost tolerant, and seral to more shade tolerant species across most of its geographic range. However, the successional status of lodgepole pine can be quite complex and depends on the specific topo-edaphic conditions at a site. Pfister and Daubenmire (1975) recognized four successional roles of lodgepole pine in the Rocky Mountains, including minor seral, dominant seral, persistent, and climax. Minor seral status occurs on productive sites where lodgepole pine growth is rapid directly following disturbance, allowing it to maintain a competitive advantage for several years. Eventually, lodgepole pine is overtaken by more shade tolerant species, is unable to reproduce, and is eliminated from the stand within a relatively short time period (<100 years). Dominant seral status occurs when lodgepole pine is able to maintain a dominant overstory position for one to two centuries. Shade tolerant species slowly gain a foothold as individual lodgepole pines die. Lodgepole pine is eventually phased out of the community as it is unable to reproduce in the understory. Persistent status occurs when lodgepole pine maintains dominance for extensive periods of time, usually as the result of periodic fires that kill shade tolerant species before they can achieve dominance. Shade tolerant species may occur as scattered individuals but fail to obtain overstory dominance. Persistent lodgepole pine forests are often considered in an extended seral state; however, the endpoint of succession is often difficult to surmise. Lastly, climax status occurs when lodgepole pine forms self-regenerating stands at sites that are unsuitable for other conifer species. Climax status is usually associated with topo-edaphic, edaphic, or micro-climatic factors, including temporary soil saturation, extremely droughty soils, nutrient poor soils, or frost-pockets.

Lodgepole pine is a monoecious, two-needle pine with thin, scaly bark that reaches 13 to 45 m tall and achieves diameters greater than 76 cm on productive sites (Anderson 2003). Cone size, shape, and serotiny vary within and among populations of lodgepole pine. In general, staminate cones are 8 to 10 mm long, while ovulate cones are 3 to 6 cm long, ovoid, and somewhat lopsided. The seeds are relatively large (4–5 mm long), winged (8–16 mm), and fall close to the parent tree. The maturation process of cones requires two years, and good seed crops are produced at one- to three-year intervals. Lodgepole pine may begin to produce seed bearing cones when as young as five years in open stands and 15 to 20 years in older, denser stands. Early seed development is an adaptation allowing relatively young stands to regenerate quickly following fire. Cone serotiny, first expressed in trees 30 to 60 years of age, is a characteristic that allows seeds to be stored on the tree in cones sealed closed by resin until the next forest fire. Serotinous cones require high temperatures (45 to 50 ºC) to melt the resin and release the seeds. The level of serotiny in populations of lodgepole pine is a legacy of fire history, geographic location, tree age, and elevation. In general, lodgepole pine stands originating from stand replacing fires feature a large number of trees with serotinous cones. Fire frequency and intensity also plays a role in cone serotiny.

Frequent, low intensity fires may not burn hot enough to stimulate the opening of serotinous cones, whereas infrequent, high intensity fires may burn too hot and destroy the seed crop.

Lodgepole pine features a number of adaptations to forest fire, including serotinous cones, thin, resinous bark, early seed production, high seedling viability and survival, and rapid seedling growth (Anderson 2003). The thin, resinous bark of lodgepole pine is highly sensitive to fire. However, mature lodgepole pine with slightly thicker bark can survive low intensity fires. Natural fire regimes in forested stands where lodgepole pine is seral depend strongly on the associated shade tolerant species. For instance, fire return intervals range between 25 and 100 years where lodgepole pine is seral to Douglas-fir, 35 and >200 years where lodgepole pine is seral to subalpine fir and Engelmann spruce, and 50 to 200 years where lodgepole pine is seral to whitebark pine. Natural fire regimes in persistent and climax lodgepole pine stands are wide ranging (25–340 years) and are strongly dependent on the interaction between disease, insect infestations, and fuel accumulation. Mixed-severity fire regimes, where a mosaic of fire severities occurs across space and time, are typical of all forests where lodgepole pine occurs. Periodic forest fire is essential for the health and maintenance of lodgepole pine forests. Fire exclusion encourages dwarf mistletoe infestations, fuel load increases due to mountain pine beetle mortality, and the establishment of shade-tolerant species, all of which increase fuel loads and the chance of damage by severe fires.

Lodgepole pine is susceptible to a variety of insect pests and diseases, the most prominent of which are described here. Of the insect pests, mountain pine beetle has been the most damaging to lodgepole pine. Large epidemics occur periodically (20–40 year intervals), killing most of the lodgepole pine in the infested area (Anderson 2003). Larger trees (≥36 cm) are generally attacked first. The adults and larvae of the mountain pine beetle feed on the phloem layer of the inner bark, eventually girdling the tree. Trees attacked by mountain pine beetle are inoculated with blue stain fungi, and individuals not killed directly by the beetle later succumb to the fungi (Hagle and others 2003). Mountain pine beetle epidemics that initiate in lower elevation lodgepole pine stands may subsequently move into upper elevation whitebark pine stands (Eggers 1990). Pine engraver beetles (*Ips* spp.) bore through the outer bark and feed in the phloem layer, introducing blue stain fungi along the way (Hagle 2003). Top-kill is a common symptom of trees attached by pine engraver beetles. When populations of pine engraver beetles are high, death of lodgepole pine may ensue. Pine cone beetle (*Conophthorus ponderosae*) and western conifer seed bug (*Leptoglossus occidentalis*) feed on the cones and developing seeds.

Comandra (*Cronartium comandrae*) and stalactiform (*Cronartium coleosporioides*) blister rusts are pathogenic fungi that cause branch and stem cankers, which can eventually girdle the branches and stem, causing top kill and death (Hagle and others 2003). Lodgepole pine is susceptible to a variety of root, butt, and stem diseases, including tomentosus root disease (*Inonotus tomentosus*), red belt fungus (*Fomitopsis pinicola*), and red ring rot (*Phellinus pini*). The lodgepole needle cast (*Lophodermella concolor*) is a fungus that attacks and kills primarily one-year-old foliage. The result is a loss in growth rate and, in smaller trees, death. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is a common parasite of lodgepole pine. Witches' brooms form on infected trees. Top kill, stem cankers, and swellings are common symptoms of dwarf mistletoe infection. Trees infected by dwarf mistletoe are also more susceptible to mountain pine beetle attack.

Prescribed fire is a common management tool for removing shade tolerant species and renewing older, languishing lodgepole pine stands (Anderson 2003). Prescribed fire is an effective method for eliminating lodgepole pine dwarf mistletoe from infected stands. Stand-replacing burns should be used in order to destroy all infected individual trees, which would otherwise act as a source of infection in the regenerating stand. Prescribed fire can also be used in fuels reduction and site preparation in conjunction with harvest and subsequent regeneration. Effective control of pine engraver beetles, which develop in logging slash, may be accomplished by burning slash following timber operations. Mountain pine beetle infestations can be controlled using silvicultural techniques. In stands with high density of suitable sized host trees (≥36 cm), clear-cutting followed by burning of logging slash is an effective method of control. In stands with high volume of smaller trees, selectively harvesting the larger individuals can help control outbreaks of mountain pine beetle. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control of mountain pine beetles in lodgepole pine stands.

Lodgepole pine stands have been managed extensively for timber harvest largely due to its rapid growth, broad environmental tolerance, and consistent regeneration. Applicable silvicultural methods include clear-cutting, shelterwood, and group selection. The appropriate silivicultural method depends on management goals, stand conditions, windfall potential, disease and insect susceptibility, and fire potential. For instance, in stands with high windfall potential due to shallow soils, high water table, low stand density, or high exposure to wind, a silivicultural method that minimizes the risk of increased windfall potential of remaining trees, such as clear-cutting, should be utilized. In serotinous stands, logging slash provides a seed source. Slash should be burned in order to open the cones, release nutrients, reduce fuels, and enhance regeneration. In non-serotinous stands, careful consideration should be given to harvest opening size in relation to adjacent lodgepole pine seed trees. Alexander (1986), Alexander and Edminster (1981), and Benson (1982) provided in-depth reviews of silivicultural techniques in lodgepole pine forests.

Lodgepole pine is low in palatability and nutrient content; however, mule deer, moose, and elk will browse lodgepole pine when other food is scarce (Anderson 2003). Snowshoe hare, pocket-gophers, voles, squirrels, porcupines, and black bear feed on the cambium of lodgepole pine. Red crossbills and red squirrels rely heavily on the seeds of lodgepole pine, while blue grouse utilize the seeds and needles for sustenance. Woodpeckers feed on the larvae of mountain pine beetles, which develop just under the outer bark. Lodgepole pine forests provide nesting sites for northern goshawks. Lodgepole pine is highly recommended for rehabilitation of disturbed sites.

Lodgepole Pine/Oregon Grape, Agneston Family Ecological Type

Pinus contorta var. *latifolia/Mahonia repens*, Agenston Family Ecological Type

PICOL/MARE11, Agneston Family ET

N = 6

Distribution

The lodgepole pine/Oregon grape, Agneston Family Ecological Type occurs in the southern study area within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). This ecological type occurs from northeast of Dickinson Park to just southwest of Limestone Mountain. It is a component of map unit 43LF. This ecological type occurs on the Flathead Sandstone Formation on northeast-facing slopes.

Environment

Aspect: East-northeast [1], northeast [3], north-northeast [2]

Landforms and Landscape Position: Footslopes and lower backslopes.

Parent Materials: Colluvium and residuum.

Bedrock for this ET consists of various members of the finer grained or lower member of the Flathead Sandstone Formation as described by Bell and Middleton (1978). The lower member of the Flathead Formation is characterized by medium-grained, clean sandstone that is locally shaley or comglomeratic at the base. In the southern geographic extent of this ET, around Ed Young Basin and Limestone Mountain, parent materials tend to be interbedded sandstone and shale colluvium over residuum. In the northern geographic extent of this ET, parent materials on backslopes tend to be sandstone colluvium over sandstone residuum, while parent materials on footslopes tend to be sandstone colluvium over sandy shale residuum.

Bedrock: Cambrian sandstone, shale, and sandy-shale.

Bedrock for this ET consists of various members of the finer-grained or lower member of the Flathead Sandstone Formation as described by Bell and Middleton (1978). The lower member of the Flathead Formation is characterized by medium-grained, clean sandstone that is locally shaley or comglomeratic at the base. In the southern geographic extent of this ET, around Ed Young Basin and Limestone Mountain, bedrock tends to be interbedded sandstone and shale.

In the northern geographic extent of this ET, bedrock on backslopes tends to be sandstone, while bedrock on footslopes tended to be sandy shale.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 56 to 65 cm.

Additional environment data summaries are provided in Table 68.

Potential natural vegetation

The potential natural vegetation of this ecological type is lodgepole pine/Oregon grape community type. Lodgepole pine is the projected climax dominant tree species on unproductive sites. Subalpine fir is the projected climax dominant tree species on the coldest sites, where potential natural vegetation is predicted to be either the subalpine fir/Oregon grape or subalpine fir/heartleaf arnica habitat types. Lodgepole pine is always found vigorously regenerating in the understory tree canopy layer especially at early seral sites. Douglas-fir seedlings may occur in the understory directly following disturbance but are projected to decrease in abundance as lodgepole pine monopolizes the overstory and forms a closed canopy. Quaking aspen occurs sporadically in all layers of the tree canopy. Oregon grape and/or Oregon boxleaf, and russet buffaloberry were always present at low abundance in the shrub layer. Snowbrush ceanothus and grayleaf red raspberry are indicative of early seral sites. The understory layers of recently burned sites were highly depauperate, a result of the intense shading induced by dense lodgepole pine regeneration. Common herbaceous species include Wheeler's bluegrass, heartleaf arnica, white-flowered hawkweed, and Ross' sedge. Herbaceous species common to early seral stands include smooth brome and fireweed. Summaries of species constancy/cover and stand characteristics are provided in Tables 69 and 70, respectively.

Soils

Soils in the PICOL/MARE11, Agneston Family ET are moderately deep and deep with a high degree of soil development, high coarse fragments (avg. 74%), and strong clay illuviation into subsurface soil horizons (avg. 23%). A thin (1–3 cm thick) litter layer occurs at the surface. A typical soil features an E/Bt/C-Cr-R horizonation. Distinguishing soil horizons include an ochric epipedon

(avg. 11 cm thick), and an argillic horizon (avg. 40 cm thick). Inceptisols lacked an argillic horizon, featuring instead a cambic horizon (48 cm thick). One soil featured a thick umbric epidepon (36 cm thick). Particle size class was primarily loamy-skeletal with one soil of the fine-loamy class. The soils were classified as Eutric Haplocryalfs [1], Typic Haplocryalfs [3], Umbric Haplocryalfs [1], and Typic Eutrocryepts [1]. The clay-rich soils of this ET are in large part related to the fine-grained parent materials, including sandy-shale and shale, which have low resistance to weathering. The result is an abundance of clay-sized soil particles. The E-horizon represents a zone of eluviation where clay particle and organic matter have been stripped out and deposited deeper in the soil profile, typically just above a restricting layer such as an R- or Cr-horizon.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Typic Haplocryalfs

Oi—0 to 2 cm: slightly decomposed plant material; abrupt smooth boundary.

E—2 to 13 cm: brown (10YR 4/3) cobbly fine sandy loam, light brownish gray (10YR 6/2), dry; 58% sand; 17% clay; weak medium granular structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; and few fine roots and common medium roots and common coarse roots and common very fine roots; few fine and common medium and common coarse and common very fine pores; 6% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 9% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; abrupt smooth boundary.

Bt1—13 to 36 cm: brown (7.5YR 4/4) very cobbly sandy clay loam, pale brown (10YR 6/3), dry; 64% sand; 22% clay; weak fine subangular blocky structure, and moderate medium subangular blocky structure; friable, hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; clay films on surfaces along pores and clay films on surfaces along root channels and 17% distinct clay films on all faces of peds; 12% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 16% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 27% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; gradual wavy boundary.

Bt2—36 to 62 cm: dark yellowish brown (10YR 4/4) extremely cobbly sandy clay loam, light brownish gray (10YR 6/2), dry; 59% sand; 27% clay; moderate fine subangular blocky structure, and weak very fine subangular blocky structure; friable, extremely hard, moderately sticky, moderately plastic; common fine roots and common medium roots and few coarse roots and few very fine roots; common fine and common medium and few coarse and few very fine pores; clay films on surfaces along pores and 5% faint clay films on all faces of peds; 19% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 24% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 36% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; gradual wavy boundary.

R—62 cm: bedrock.

Ecology

The PICOL/MARE11, Agneston Family ET was characterized by recent disturbance, including forest fire and logging. The lodgepole pine cones in these stands are predominantly serotinous, regeneration was vigorous, and stand age was typically less than 100 years. The moderately deep-to-deep, clay-rich soils associated with the PICOL/MARE11, Agneston Family ET have greater available water-holding capacity and cation exchange capacity (i.e., a greater ability to retain nutrients) than shallower, coarser-grained soils on the Flathead Formation. Lodgepole pine reach large sizes quickly and form uniform, even-aged stands in 120 to 150 years.

Succession

The successional status of the PICOL/MARE11, Agneston Family ET is considered to be dominant seral on colder, mesic sites and climax on warmer, drier sites (Pfister and Daubenmire 1975). Sample sites fell within the LP-1 (immature stands) and LP-2 (mature stands) post-fire successional stages of the "Persistent Lodgepole Pine Community Types" of Bradley and others (1992). In stands where lodgepole pine is potential natural vegetation, lodgepole pine is the only tree present at the site. After stand-replacing disturbance events and in the absence of severe fire, a brief (10–20 years) herbaceous/shrub stage is followed by (1) a lodgepole pine seedling/sapling stage (10–40 years), (2) pole-sized stage (40–150 years), (3) mature forest (150–300 years), and (4) over mature stage (>300 years), at which point the overstory begins to break up and an uneven-aged stand develops. At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. At stages 2 through 4, low to moderate fires thin stands while severe fires reset the successional pathway. The climax forest approximates an all-aged lodgepole pine stand.

In stands seral to subalpine fir, the successional pathway is very similar to that described above, with the exception that subalpine fir seedlings are present in the understory of the mature forest stage (Bradley and others 1992). Subalpine fir seedlings may occur in the understory of the pole-sized stage if a low to moderate fire thins the stand, providing openings in which subalpine fir may establish. Subalpine fir gradually gains dominance as individual lodgepole pine, removed by mountain pine beetle and dwarf mistletoe mortality, are replaced in the overstory by subalpine fir. In seral stands where quaking aspen co-occurs with lodgepole pine, lodgepole pine seedlings and quaking aspen sprouts both establish during the initial herbaceous/shrub phase (Bradley and others 1992). Quaking aspen quickly overtops lodgepole pine seedlings during the seedling/sapling stage, restricting lodgepole pine to openings in the canopy where quaking aspen suckers are absent. At this stage, low to moderate fires favor lodgepole pine seedling establishment and quaking aspen sprouts by opening up the stand and stimulating root suckering of quaking aspen. In the absence of fire, the quaking aspen overstory eventually breaks up and a mixed conifer stand develops featuring lodgepole pine in the overstory and subalpine fir in the understory. As the stand approaches climax, lodgepole pine drops out of the overstory and quaking aspen occasionally survives in small, emaciated patches.

Management considerations

The PICOL/MARE11, Agneston Family ET shows the most promise for timber management of all Ecological Types on the Flathead Sandstone Formation. The location of this ET on the lower half of the Flathead Formation and the gentle slopes (avg. 18%) provide for easy access to logging equipment. However, the clay-rich soils are at increased risk of compaction by heavy equipment. Soil compaction can lead to reduced rates of water infiltration and lower soil volume, factors resulting in reduced root penetration and overall water availability (Meurisse and others 1991). Forest managers should limit the number of logging roads developed in these stands and require equipment operators to remain on designated roads. Downed logs located away from roads may be retrieved using a cable and winch system attached to skidders.

The highly productive nature of this ET makes it ideal for short rotation harvests of large, high-quality timber. Since forested stands of this ecological type tend to be even aged, timber harvest should occur shortly after stands reach maturity, before mountain pine beetle outbreaks reach epidemic proportions. Harvest schedules should be designed to create age-class mosaics of the PICOL/MARE11, Agneston Family ET across the landscape (Bradley and others 1992). Broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe (Anderson 2003) and open serotinous cones. Broadcast burning also removes duff, prepares mineral soil for lodgepole pine regeneration, and results in a pulse of biologically available nitrogen in the soils (Giardina and Rhoades 2001). Russet buffaloberry is important during the initial stages of stand regeneration due to its ability to transform atmospheric nitrogen into biologically available forms. Forage and browse production is high during the initial stages of this ecological type. Forage production drops continually as stand age increases, and Oregon grape may be the only species with appreciable forage value in climax stands. However, these stands are located directly adjacent to mountain big sagebrush and grassland communities and provide important thermal and hiding cover for deer and elk.

These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics should consider closely monitoring the PICOL/MARE11, Agneston Family ET for signs of beetle activity. Fuel loads in these young stands are not suited to support large, stand-replacing burns. Risk of catastrophic wildfire increases with stand age as (1) seedling density increases, creating ladder fuels necessary to carry fire into tree crowns; and (2) mountain pine beetle mortality results in increased fuel loads.

Similar ecological types

Ecological Type 1

Type: Lodgepole pine/heartleaf arnica, Como Family ET

Floristic differences: The two types differ floristically in that PNV in the Como Family ET is the lodgepole pine/heartleaf arnica or lodgepole pine/common juniper community types, while PNV in the Agneston Family ET is lodgepole pine/Oregon grape community type.

Environmental differences: The two types differ in that the soils in the Como Family ET are typically moderately deep and deep Entisols and Inceptisols, while the soils in the Agneston Family ET are typically deep, clay-rich Alfisols. Also, the Como Family ET occurs on upper backslope and shoulder positions, while the Agneston Family ET occurs on lower backslope and footslope positions.

Table 68—Summary of environmental variables for the PICOL/MARE11, Agneston Family ET.

General environment	**Average**	**Min**	**Max**
Elevation (m)	2,612	2,476	2,751
Slope (%)	18	9	42
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	609	561	653
Degree days	16,870	15,490	18,330
Frost-free days	19.9	19.2	20.6
Site water balance (mm/year)	-305	-351	-266
Average annual temperature (°C)	2.0	1.5	2.6
Total annual potential evapotranspiration (mm)	610	561	681
Summer radiation (KJ)	20,030	19,790	20,330
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	74	49	86
Clay (% in particle size control section)	23	18	33
pH (in particle size control section)	5.0	4.5	5.6
Available water capacity (mm/m)	50	39	66
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	7	0	20
Exposed bedrock	7	0	30
Gravel	3	0	5
Cobble	3	1	10
Stones	3	0	10
Boulders	2	0	5
Litter	26	15	30
Wood	18	10	30
Moss and lichen	1	0	2
Basal vegetation	30	20	50
Water	0	0	0

Table 69—Constancy/cover table for common plant species occurring in the PICOL/MARE11, Agneston Family ET.

Characteristic	Species:		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	19	10	35
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	12	3	40
Seedlings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	80	5	3	10
Shrubs:						
CEVE	*Ceanothus velutinus*	shinyleaf ceanothus	40	2	1	3
JUCOD	*Juniperus communis* var. *depressa*	common juniper	40	5	5	5
MARE11	*Mahonia repens*	Oregon grape	100	3	1	5
ROWO	*Rosa woodsii*	woods rose	40	1	1	1
SHCA	*Shepherdia canadensis*	russet buffaloberry	100	2	1	5
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	40	1	1	1
AGGL	*Agoseris glauca*	pale agoseris	40	1	1	1
ANRO2	*Antennaria rosea*	rosy pussy-toes	40	1	1	1
ANUM	*Antennaria umbrinella*	umber pussy-toes	40	3	1	5
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	5	3	10
CHAN9	*Chamerion angustifolium*	fireweed	40	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	40	2	1	3
EREA	*Erigeron eatonii*	Eaton's fleabane	40	2	1	3
FRVI	*Fragaria virginiana*	Virginia strawberry	60	2	1	3
HIAL2	*Hieracium albiflorum*	white-flowered hawkweed	80	2	1	5
ORSE	*Orthilia secunda*	sidebells wintergreen	40	1	1	1
OSDE	*Osmorhiza depauperata*	blunt-fruited sweet-cicely	40	2	1	3
VIOLA	*Viola*	violet	40	1	1	1
Grasses:						
ELEL5	*Elymus elymoides*	squirreltail	40	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	6	3	15
TRSP2	*Trisetum spicatum*	spike trisetum	40	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	80	2	1	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 70—Stand characteristics for the PICOL/MARE11, Agneston Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------Centimeters-------			
PICOL	17.4	6.9–41.3	22.9	11.9–31.8	637	240–1,210

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PICOL	19.1	16	91

Lodgepole Pine/Common Juniper, Holland Lake Family Ecological Type

Pinus contorta var. *latifolia/Juniperus communis* var. *depressa*, Holland Lake Family Ecological Type

PICOL/JUCOD, Holland Lake ET

N = 4

Distribution

The lodgepole pine/common juniper, Holland Lake Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ecological type occurs on the lower extent (approximately east of the Louis Lake Loop Road) of the Louis Lake moraine unit. It is a component of map unit 327L.

Environment

Aspect: North-northeast [2], southeast [1], west [1].

Landforms and Landscape Position: Kames. Summit, shoulder, backslope, footslope.

Parent Materials: Glacial till

Bedrock: Granodiorite of the Louis Lake Pluton

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 60 cm to 63 cm.

Additional environment data summaries are provided in Table 71.

Potential natural vegetation

At present, the vegetation of this ecological type falls into one of two community types: lodgepole pine/common juniper or the lodgepole pine/russet buffaloberry (Steele and others 1983). Based on examination of adjacent climax stands, potential natural vegetation of the lodgepole pine/common juniper and lodgepole pine/russet buffaloberry community types is projected to be whitebark pine/common juniper habitat type on upper elevation exposed sites and subalpine fir/common juniper habitat type at more sheltered locations. On extremely unproductive sites, especially on droughty sites at lower elevations, the lodgepole pine/russet buffaloberry community type may represent potential natural vegetation. Common juniper is always present in the shrub layer. In lodgepole pine/russet buffaloberry community type, common juniper is present at low abundance relative to russet buffaloberry. Other shrub species are either absent or occur as scattered individuals, except kinnikinnick, which may occur at high abundance when present. Relative to other lodgepole pine communities, the herbaceous layer of the lodgepole pine/common juniper, Holland Lake ET is species rich. Heartleaf arnica, manyray goldenrod, and harebell are the most common forbs. White-flowered hawkweed and alpine leafybract aster may be relatively abundant when they occur. Ross' sedge, squirreltail, and Wheeler's bluegrass are the most common graminoids. Summaries of species constancy/cover and stand characteristics are provided in Tables 72 and 73, respectively.

Soils

The soils in this ET are relatively old as they are derived from Bull Lake (>200–130 Ka) and older Pinedale age glacial till (22–15 Ka) (Dahms, D.E., pers. comm.). These soils have had a relatively long time to develop compared to soils derived from younger deposits. The soils were deep (>1 m), low in rock fragments (avg. 41%), and moderate high in illuvial clay (avg. 17%). Soils in this ET typically feature an A/E/Bt/CB-C horizon. Depth to C- or CB material tended to be greater than one meter. Diagnostic soil horizons include an ochric epipedon (avg. 8 cm thick), and an argillic horizon (avg. 82 cm thick). Inceptisols featured a cambic horizon (avg. 58 cm thick) in place of an argillic horizon. Particle size class was primarily loamy-skeletal with one sandy-skeletal soil. Soils included Eutric Glossocryalfs [2], Typic Eutrocryepts [1], and Typic Dystrocryepts [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Eutric Glossocryalfs

Oi—0 to 2 cm: slightly decomposed plant material; abrupt wavy boundary.

Oe—2 to 3 cm: moderately decomposed plant material; abrupt wavy boundary.

A—3 to 6 cm: very dark brown (10YR 2/2) very fine sandy loam, very dark grayish brown (10YR 3/2), dry; 54% sand; 9% clay; weak fine subangular blocky structure, and weak fine granular structure; very friable, soft, nonsticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 4% nonflat subrounded indurated 76- to 250- mm unspecified fragments and 9% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.5; abrupt wavy boundary.

E—6 to 18 cm: brown (10YR 4/3) medium gravelly sandy loam, light brownish gray (10YR 6/2), dry; 60% sand; 16% clay; weak coarse subangular blocky structure, and weak very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; many fine roots and common medium roots and common coarse roots and common very fine roots; many fine and common medium and common coarse and common very fine pores; 8% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 18% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.7; gradual wavy boundary.

EBt—18 to 45 cm: pale brown (10YR 6/3) very gravelly sandy loam, light gray (10YR 7/2), dry; 75% sand; 14% clay; weak very fine subangular blocky structure, and weak fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common very fine and fine roots and common medium roots and common coarse roots and common very coarse roots; common very fine and fine and common medium and common coarse and common very coarse pores; 5% patchy faint clay films on all faces of peds; 11% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 45% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.9; 65% of horizon is “E”; 35% of horizon is Bt.; clear wavy boundary.

Bt1—45 to 79 cm: brown (10YR 4/3) extremely gravelly sandy clay loam, pale brown (10YR 6/3), dry; 70% sand; 24% clay; moderate fine subangular blocky structure, and moderate medium subangular blocky structure; firm, hard, moderately sticky, moderately plastic; common very fine and fine roots and few medium roots; common very fine and fine and few medium pores; 3% patchy faint clay films on surfaces along root channels and 4% patchy distinct clay films on rock fragments and 5% patchy faint clay films on all faces of peds; 23% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 54% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.7;Gravel: 3% paragravel and 51% gravel.; clear wavy boundary.

BCt—79 to 102 cm: olive brown (2.5Y 4/3) very cobbly sandy loam, light yellowish brown (2.5Y 6/3), dry; 78% sand; 18% clay; weak medium subangular blocky structure, and moderate fine subangular blocky structure; friable, hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 2% patchy faint clay films on all faces of peds; 21% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 29% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6; Gravel: 2% paragravel and 27% gravel.

Ecology

Lodgepole pine is the first tree species to colonize granitic glacial moraines at lower elevations in subalpine forests of the eastern slope of the WRR following disturbance. The PICOL/JUCOD, Holland Lake Family ET was characterized by relatively large diameter trees (avg. 20.8 cm DBH) and a young age distribution (50 to 125 years). The larger diameter of lodgepole pine in this ecological type relative to stand age suggests that these sites are some of the most productive lodgepole pine Ecological Types described for the eastern slope of the WRR. The soils, formed from older till deposits, have had significantly more time to develop than soils formed from younger till deposits. As a result, the soils in this ET were more highly developed and finer-grained than the soils from younger till deposits, including the PICOL/SHCA, Bohica and PIAL/VASC, Salt Chuck Family Ecological Types. Alfisols tend to have some of the highest cation exchange capacities and nutrient retention capabilities of all western forest soils, a characteristic that, in part, helps explain the higher productivity in this ecological type (Meurisse and others 1991). Also, the higher content in these soils added to the available water holding capacity, another factor influencing productivity.

Succession

The successional status of the PICOL/JUCOD, Holland Lake Family ET is considered to be dominant seral on colder, moist sites and persistent or climax on warmer, droughty sites (Pfister and Daubenmire 1975). This ET falls within the LP-2 (mature stands) post-fire successional stage of the “Persistent Lodgepole Pine Community

Types" of Bradley and others (1992). Lodgepole pine is the only tree present at the site in stands where lodgepole pine is potential natural vegetation. After stand-replacing disturbance events, and in the absence of severe fire, a brief (10–20 years) herbaceous/shrub stage is followed by (1) a lodgepole pine seedling/ sapling stage (10–40 years), (2) pole-sized stage (40–150 years), (3) mature forest (150–300 years), and (4) over mature stage (>300 years), at which point the overstory begins to break up and an uneven-aged stand develops. At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. At stages 2 through 4, low to moderate fires thin stands while severe fires reset the successional pathway. The climax forest approximates an all-aged lodgepole pine stand.

In mid- and lower elevation subalpine stands seral to subalpine fir or whitebark pine, the successional pathway is very similar to that previously described, except that subalpine fir or whitebark pine seedlings are present in the understory of the mature forest stage (Bradley and others 1992). Subalpine fir or whitebark pine seedlings may occur in the understory of the pole-sized stage if a low to moderate fire thins the stand, providing openings in which the more shade tolerant species may establish. In stands seral to subalpine fir, the stand is gradually taken over by subalpine fir as individual lodgepole pine, removed by mountain pine beetle and dwarf mistletoe mortality, are replaced in the overstory by subalpine fir. In stands seral to whitebark pine, succession takes place very slowly as the slightly more shade tolerant (relative to lodgepole pine) whitebark pine steadily increases in abundance in the overstory (Steele and others 1983). Lodgepole pine often co-dominates in climax whitebark pine stands at these sites.

Management considerations

The PICOL/JUCOD, Bohica Family ET featured an even-age distribution and serotinous cones. This ET is not suited for timber harvest due to the extremely bouldery soil surface associated with the Louis Lake moraine. Mountain pine beetle epidemics often begin in lower elevation lodgepole pine stands and move into upper elevation forests (Eggers 1990). These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics in whitebark pine forests may want to consider monitoring the PICOL/JUCOD, Holland Lake Family ET for signs of beetle activity. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques to control mountain pine beetles in lodgepole pine stands. Many of these stands are located in areas frequented by recreationists. Managers should consider leaving buffer zones along roads to maintain aesthetic appeal following silvicultural treatments. Buffer zones should also be created around the many kettle lakes associated with this ecological type.

Broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe (Anderson 2003) and open serotinous cones. Broadcast burning also removes duff, prepares mineral soil for lodgepole pine regeneration, and results in a pulse of biologically available nitrogen in the soils (Giardina and Rhoades 2001). Russet buffaloberry is important during the initial stages of stand regeneration due to its ability to transform atmospheric nitrogen into biologically available forms.

Similar ecological types

Ecological Type 1

Type: Lodgepole pine/russet buffaloberry, Bohica Family ET

Floristic differences: The two types are similar floristically in that potential natural vegetation in both types may include the lodgepole pine/russet buffaloberry community type.

Environmental differences: The two types differ environmentally in that the Holland Lake Family ET occurs exclusively on the lower section of the Louis Lake moraine and features soils derived from Bull Lake age till, while the Bohica Family ET occurs on lower elevation (< approximately 3,000 m) glacial till deposits other than the Louis Lake moraine and features soils derived from Pinedale age till.

Table 71—Summary of environmental variables for the PICOL/JUCOD, Holland Lake Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,606	2,572	2,662
Slope (%)	17	6	29
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	612	602	633
Degree days	16,520	15,910	16,850
Frost-free days	19.7	19.4	19.9
Site water balance (mm/year)	-283	-305	-253
Average annual temperature (°C)	1.9	1.6	2.0
Total annual potential evapotranspiration (mm)	635	627	639
Summer radiation (KJ)	20,450	20,140	20,800
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	41	8	77
Clay (% in particle size control section)	17	11	24
pH (in particle size control section)	5.3	4.9	5.7
Available water capacity (mm/m)	84	57	117
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	0	5
Exposed bedrock	0	0	0
Gravel	1	0	5
Cobble	4	0	10
Stones	5	0	10
Boulders	9	0	15
Litter	42	23	65
Wood	18	5	35
Moss and lichen	2	0	5
Basal vegetation	18	15	20
Water	0	0	0

Table 72—Constancy/cover table for common plant species occurring in the PICOL/JUCOD, Holland Lake Family ET.

Charactertistic	Species		Con	Cov	Min	Max
			Percent			
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	28	20	35
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	4	3	5
Seedlings:						
PIAL	*Pinus albicaulis*	whitebark pine	100	2	1	3
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	4	3	5
Shrubs:						
ARUV	*Arctostaphylos uva-ursi*	kinnikinnick	100	8	1	15
JUCOD	*Juniperus communis* var. *depressa*	common juniper	100	4	3	5
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	3	3	3
CARO2	*Campanula rotundifolia*	harebell	100	1	1	1
FRVI	*Fragaria virginiana*	Virginia strawberry	100	1	1	1
LUAR3	*Lupinus argenteus*	silvery lupine	100	2	1	3
PYCH	*Pyrola chlorantha*	green wintergreen	100	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	100	1	1	1
SYFO2	*Symphyotrichum foliaceum*	alpine leafybract aster	100	6	1	10
Grasses:						
ELEL5	*Elymus elymoides*	squirreltail	100	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	100	3	3	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 73—Stand characteristics for the PICOL/JUCOD, Holland Lake Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m²/ha---		*-------Centimeters-------*			
PIAL	2.3	—	25.7	—	44	—
PICOL	29.8	25.3–34.4	20.8	10.7–44.7	1163	385–1,899

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
PIAL	25.7	12	87
PICOL	23.6	16	98

Lodgepole Pine/Russet Buffaloberry, Bohica Family Ecological Type

Pinus contorta var. *latifolia/Shepherdia canadensis*, Bohica Family Ecological Type

PICOL/SHCA, Bohica Family ET

N = 4

Distribution

The lodgepole pine/russet buffaloberry, Bohica Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ecological type occurs in the area around Worthen Meadows Reservoir southeast to the headwaters of Sawmill Creek and east to the junction of Townsend and Sawmill Creeks. It is a component of map units 327W and 351L.

Environment

Aspect: North [1], north-northeast [2], north-northwest [1]

Landforms and Landscape Position: Glacial moraines. Upper backslopes and shoulders.

Parent Materials: Glacial till.

In the area around Worthen Meadows, Frye Lake, and the headwaters of Sawmill Creek, parent material tended to be granodiorite glacial till. In Burnt Gulch and the lower reaches of Sawmill Creek parent materials tended to be Flathead Sandstone colluvium over granodiorite glacial till.

Bedrock: Granodiorite of the Louis Lake Pluton, Flathead Sandstone

In the area around Worthen Meadows, Frye Lake, and the headwaters of Sawmill Creek, bedrock is granodiotire of the Louis Lake Pluton. In Burnt Gulch and the lower reaches of Sawmill Creek, bedrock is Flathead Sandstone.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 57 to 64 cm.

Additional environment data summaries are provided in Table 74.

Potential natural vegetation

At present, the vegetation of this ecological type falls within either the lodgepole pine/russet buffaloberry or lodgepole pine/Ross' sedge community type. These community types may occur on a number of habitat types (Steele and others 1983). Based on examination of adjacent climax stands, potential natural vegetation of the lodgepole pine/russet buffaloberry community type within this ET is projected to be whitebark pine/common juniper habitat type on upper elevation exposed sites and subalpine fir/heartleaf arnica habitat type on more sheltered sites. Potential natural vegetation is projected to be subalpine fir/Ross' sedge habitat type. On extremely unproductive sites, especially on droughty sites at lower elevations, the lodgepole pine/russet buffaloberry community type may represent potential natural vegetation.

Lodgepole pine is always found vigorously regenerating in the understory tree canopy layer. Whitebark pine regeneration occurs in the understory of higher elevation sites. At more mesic microsites, quaking aspen may occur in the lower tree canopy layer.

In the lodgepole pine/russet buffaloberry community type, russet buffaloberry dominates the shrub layer, while common juniper and kinnikinnick were always present at low abundance. Prickly currant and Scouler's willow may occur at more mesic microsites. In the lodgepole pine/Ross' sedge community type, shrub species occur at low abundance scattered throughout the understory. Kinnikinnick was present at low abundance at all sites sampled.

A low cover of herbaceous species and an abundance of exposed pine needle litter are common to both community types. In the lodgepole pine/russet buffaloberry community type, Wheeler's bluegrass is the most consistent herbaceous species present. In the lodgepole pine/Ross' sedge community type, some common herbaceous species include Ross' sedge, heartleaf arnica, Wheeler's bluegrass, manyray goldenrod, and silvery lupine. Summaries of species constancy/cover and stand characteristics are provided in Tables 75 and 76, respectively.

Soils

The soils in this ET are relatively young as they are derived from Pinedale age glacial till deposited between 22 and 15 Ka (Dahms 2004b). These soils have had relatively little time to develop compared to soils derived from older glacial till deposits, including Bull Lake till (>200-130 Ka). The soils were deep (>1 m) and moderately high in rock fragments (avg. 39%); however, they were sandy, minimally developed, and featured very little clay illuviation (avg. 11%). A thin (avg. 4 cm thick) litter layer may occur at the surface. A typical soil features an A/Bw/CB-C horizonation. The soils of one plot featured an 18-cm thick highly leached eluvial (E-) horizon. Diagnostic soil horizons include a thin ochric epipedon (avg. 12 cm thick),

and a cambic horizon (avg. 51 cm thick). Entisols featured no diagnostic subsurface horizons. Particle size class included coarse-loamy [2], loamy-skeletal [1], and sandy-skeletal [1]. Soils were Typic Eutrocryepts [3] and Typic Cryorthents [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive Typic Eutrocryepts

Oi—0 to 2 cm: slightly decomposed plant material; abrupt smooth boundary.

A—2 to 10 cm: 65% dark grayish brown (10YR 4/2) and 35% dark brown (10YR 3/3) sandy loam, 65% light brownish gray (10YR 6/2) and 35% brown (10YR 5/3), dry; 64% sand; 10% clay; weak medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 11% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; clear smooth boundary.

Bw—10 to 41 cm: dark grayish brown (10YR 4/2) sandy loam, light brownish gray (10YR 6/2), dry; 70% sand; 11% clay; weak medium subangular blocky structure, and weak fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 5% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; clear smooth boundary.

CB—41 to 110 cm: 50% light brownish gray (2.5Y 6/2) and 50% dark yellowish brown (10YR 4/4) medium gravelly sandy loam, 50% light gray (2.5Y 7/2) and 50% very pale brown (10YR 7/3), dry; 77% sand; 12% clay; massive; friable, moderately hard, slightly sticky, nonplastic; few fine roots and few medium roots and common very fine roots; many fine and common medium and common very fine pores; 20% patchy faint clay films on rock fragments; 16% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6.

Ecology

Lodgepole pine is the first tree species to colonize glacial moraines at lower elevations in subalpine forests of the eastern slope of the WRR following disturbance. The PICOL/SHCA, Bohica Family ET was characterized by small diameter trees (avg. 17.3 cm DBH) and a relatively young age distribution (81 to 133 years). The small diameter of lodgepole pine in this ecological type relative to stand-age suggests that these sites are not as productive as other lodgepole pine Ecological Types described for the eastern slope of the WRR. The soils, formed from younger till deposits, have had significantly less time to develop than soils formed from older till deposits. As a result, the soils in this ET were less developed and coarser-grained than the soils from older till deposits, including PICOL/JUCOD, Holland Lake Family ET. The low available water-holding capacity of these minimally developed, coarse-grained soils may account, in part, for the low productivity of this ecological type. Also, coarse-textured soils, such as those in the PICOL/SHCA, Bohica Family ET, usually have low cation exchange capacities, which, when combined with a Udic moisture regime, can result in significant nutrient losses from the soil (Fahey and others 1985; Meurisse and others 1991).

Succession

The successional status of the PICOL/SHCA, Agenston Family ET is considered to be dominant seral on colder, more moist sites and persistent or climax on warmer, droughty sites (Pfister and Daubenmire 1975). This ET falls within the LP-2 (mature stands) post-fire successional stage of the “Persistent Lodgepole Pine Community Types” of Bradley and others (1992). In stands where lodgepole pine is potential natural vegetation, lodgepole pine is the only tree present at the site. After stand-replacing disturbance events and in the absence of severe fire a brief (10–20 years) herbaceous/shrub stage is followed by (1) a lodgepole pine seedling/ sapling stage (10–40 years),

(2) pole-sized stage (40-150 years), (3) mature forest stage (150-300 years), and (4) over-mature stage (>300 years), at which point the overstory begins to break up and an uneven-aged stand develops. At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. At stages 2 through 4, low to moderate fires thin stands while severe fires reset the successional pathway. The climax forest approximates an all-aged lodgepole pine stand.

In mid- and lower elevation subalpine stands of seral to subalpine fir or whitebark pine, the successional pathway is very similar to that previously described, except that subalpine fir or whitebark pine seedlings are present in the understory of the mature forest stage (Bradley and others 1992). Subalpine fir or whitebark pine seedlings may occur in the understory of the pole-sized stage if a low to moderate fire thins the stand, providing openings in which the more shade tolerant species may establish. In stands seral to subalpine fir, the stand is gradually taken over by subalpine fir as individual lodgepole pine, removed by mountain pine beetle and dwarf mistletoe mortality, are replaced in the overstory by subalpine fir. In stands seral to whitebark pine, succession takes place very slowly as the slightly more shade tolerant (relative to lodgepole pine) whitebark pine steadily increases in abundance in the overstory (Steele and others 1983). Lodgepole pine often co-dominates in climax whitebark pine stands at these sites.

Management considerations

The PICOL/SHCA, Bohica Family ET featured an uneven age distribution. The larger trees in these stands are approaching the optimal size for mountain pine beetle attack (~36 cm), while the smaller trees are unhealthy and suffering from dwarf mistletoe. The appropriate management of this ecological type includes timber harvest followed by broadcast burning of slash material. Broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe (Anderson 2003) and open serotinous cones. Broadcast burning also removes duff, prepares mineral soil for lodgepole pine regeneration, and results in a pulse of biologically available nitrogen in the soils (Giardina and Rhoades 2001).

Since the cones in this ecological type are non-serotinous, careful consideration should be given to harvest opening size in relation to adjacent lodgepole pine seed trees. Also, windfall is a potential hazard as these stands are located on exposed upper backslope and shoulder positions. A shelterwood cutting or a larger number of smaller clear-cuts should provide the proper balance between protection from windfall and seed source. Many of these stands are located in areas frequented by recreationists. Managers should consider leaving buffer zones along roads to maintain aesthetic appeal following timber harvest. Prescribed fire may be used as a management tool in areas located away from high human use and in areas where the terrain makes logging inefficient or impossible, including the headwaters of Sawmill Creek and Burnt Gulch Creek. The intensity of prescribed fires should approximate those of stand replacing burns.

These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics should consider closely monitoring the PICOL/SHCA, Bohica Family ET for signs of beetle activity. Fuel loads in these young stands are not suited to support large, stand-replacing burns. Risk of catastrophic wildfire increases with stand age as (1) seedling density increases, creating ladder fuels necessary to carry fire into tree crowns, and (2) mountain pine beetle mortality results in increased fuel loads. Russet buffaloberry and silvery lupine are important during the initial stages of stand regeneration due to its ability to transform atmospheric nitrogen into biologically available forms.

Similar ecological types

Ecological Type 1

Type: Lodgepole pine/common juniper, Holland Lake Family ET

Floristic differences: The two types are similar floristically in that potential natural vegetation in both types may include the lodgepole pine/russet buffaloberry community type.

Environmental differences: The two types differ environmentally in that the Holland Lake Family ET occurs exclusively on the lower section of the Louis Lake moraine and features soils derived from Bull Lake age till, while the Bohica Family ET occurs on lower elevation (< approximately 3000 m) glacial till deposits other than the Louis Lake moraine and features soils derived from Pinedale age till.

Table 74—Summary of environmental variables for the PICOL/SHCA, Bohica Family ET.

General environment	Average	Min	Max
Elevation (m)	2,638	2,484	2,749
Slope (%)	17	7	43
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	611	566	644
Degree days	16,500	15,230	18,180
Frost-free days	19.8	19.1	20.6
Site water balance (mm/year)	-266	-364	-213
Average annual temperature (°C)	1.9	1.3	2.6
Total annual potential evapotranspiration (mm)	587	498	660
Summer radiation (KJ)	19,630	18,700	20,190
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	39	14	64
Clay (% in particle size control section)	11	5	15
pH (in particle size control section)	5.3	4.7	5.5
Available water capacity (mm/m)	65	33	90
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	5
Exposed bedrock	0	0	0
Gravel	1	0	2
Cobble	3	0	5
Stones	4	1	10
Boulders	9	1	20
Litter	43	20	60
Wood	20	15	30
Moss and lichen	2	2	3
Basal vegetation	16	15	20
Water	0	0	0

Table 75—Constancy/cover table for common plant species occurring in the PICOL/SHCA, Bohica Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PIAL	*Pinus albicaulis*	whitebark pine	50	5	5	5
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	10	10	10
Subominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	50	15	15	15
Saplings:						
PIAL	*Pinus albicaulis*	whitebark pine	50	1	1	1
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	12	10	15
POTR5	*Populus tremuloides*	quaking aspen	50	3	3	3
Seedlings:						
PIAL	*Pinus albicaulis*	whitebark pine	50	1	1	1
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	1	1	1
PIEN	*Picea engelmannii*	Engelmann spruce	50	1	1	1
POTR5	*Populus tremuloides*	quaking aspen	50	1	1	1
Shrubs:						
ARUV	*Arctostaphylos uva-ursi*	kinnikinnick	100	1	1	1
JUCOD	*Juniperus communis* var. *depressa*	common juniper	100	1	1	1
RILA	*Ribes lacustre*	prickly currant	50	5	5	5
RIVI3	*Ribes viscosissimum*	sticky currant	50	1	1	1
SASC	*Salix scouleriana*	Scouler's willow	50	3	3	3
SHCA	*Shepherdia canadensis*	russet buffaloberry	100	9	3	15
Forbs:						
AQCO	*Aquilegia coerulea*	Colorado blue columbine	50	1	1	1
ARCO9	*Arnica cordifolia*	heartleaf arnica	50	1	1	1
CARO2	*Campanula rotundifolia*	harebell	50	1	1	1
LUAR3	*Lupinus argenteus*	silvery lupine	50	3	3	3
ORSE	*Orthilia secunda*	sidebells wintergreen	50	1	1	1
POTEN	*Potentilla*	cinquefoil	50	1	1	1
PYCH	*Pyrola chlorantha*	green wintergreen	50	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	50	1	1	1
Grasses:						
POSE	*Poa secunda*	Sandberg bluegrass	50	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	2	1	3
TRSP2	*Trisetum spicatum*	spike trisetum	50	1	1	1
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	50	3	3	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.occurred.

Table 76—Stand characteristics for the PICOL/SHCA, Bohica Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	Average	Range	Average	Range	Average	Range
	---m^2/ha---		-------Centimeters-------			
PICOL	26.4	25.3–29.8	17.3	10.2–35.3	1,339	946–1,734

	Site tree averages		
Species	DBH	Height	Age
	Centimeters	*Meters*	*Years*
	21.6	18	106

Lodgepole Pine/Heartleaf Arnica, Como Family Ecological Type

Pinus contorta var. *latifolia/Arnica cordifolia*, Como Family Ecological Type

PICOL/ARCO9, Como Family ET

N = 8

Distribution

The lodgepole pine/heartleaf arnica, Como Family Ecological Type occurs in the southern study area within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). This ET occurs from northeast of Dickinson Park to just southwest of Limestone Mountain. It is a component of map unit 43LF. This ecological type occurs on the Flathead and Tensleep Sandstone Formations on northeast-facing slopes.

Environment

Aspect: East [3], east-northeast [1], northeast [4].

Landforms and Landscape Position: Summits, shoulders, and upper backslopes.

Parent Materials: Sandstone colluvium and residuum.

On the Flathead formation, parent material tends to be of the coarse-grained upper member of the Flathead Formation as described by Bell and Middleton (1978). The upper member of the Flathead Formation is characterized by parallel stratification with coarse- to fine-grained sandstone and localized areas of interbedded fine-grained, clayey sandstone, siltstone, and shale.

Bedrock: Flathead or Tensleep Sandstone.

On the Flathead Formation, bedrock tends to be of the coarse-grained upper member of the Flathead Formation as described by Bell and Middleton (1978).

Climate: Cryic temperature regime and Udic moisture regime on the Flathead formation. On the Tensleep Formation, soil temperature regime is Frigid and soil moisture regime is Ustic. Estimated annual precipitation ranges from 61 to 68 cm on the Flathead Formation and 55 to 61 cm on the Tensleep Formation.

Additional environment data summaries are provided in Table 77.

Potential natural vegetation

In the WRR, where this ET becomes increasingly stable in age structure compared with other locations in the Rocky Mountains, the potential natural vegetation of this ecological type is either the lodgepole pine/heartleaf arnica or lodgepole pine/common juniper community type (Steele and others 1983). Lodgepole pine is the projected climax dominant tree species on unproductive sites. On productive sites, usually where soils are locally fine-grained, this ET occupies the subalpine fir/heartleaf arnica or the subalpine fir/common juniper habitat types.

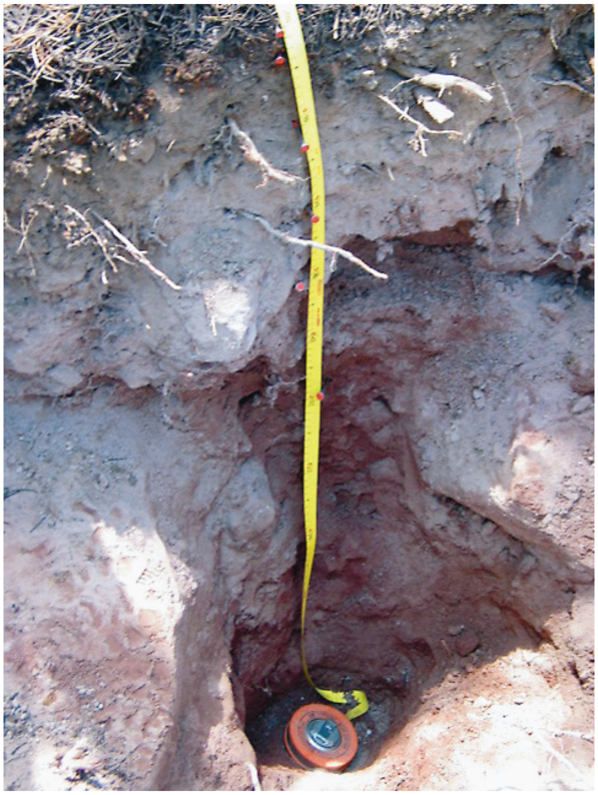
In both the lodgepole pine/heartleaf arnica and lodgepole pine/common juniper community types, lodgepole pine is always present in the overstory. Early seral sites typically exhibit a smaller size structure and open canopy layer (10-20% overstory cover). Later seral sites are typically closed canopy, and lodgepole pine regeneration is often limited to scattered seedling and understory individuals. Lodgepole pine may sometimes be accompanied by limber pine seedlings in the understory. Quaking aspen may occur in early seral stands especially on extremely rocky or more mesic microsites.

In the lodgepole pine/common juniper community type, common juniper occurs as a moderately dense shrub layer accompanied by Oregon grape and russet buffaloberry. In the lodgepole pine/heartleaf arnica community type, common juniper and Oregon grape are often present in the shrub layer at low abundance. Snowbrush ceanothus and black chokecherry are indicative of early seral stands. Scouler's willow is indicative of more mesic microsites.

Heartleaf arnica forms a prolific herbaceous layer and is always accompanied by Wheeler's bluegrass. Ross' sedge, sidebells wintergreen, slender hawkweed, and yellow coralroot are other common herbaceous species present in this ET. Summaries of species constancy/cover and stand characteristics are provided in Tables 78 and 79, respectively.

Soils

These minimally developed soils are moderately deep and deep, sandy, high in coarse fragments (avg. 75%), and low in illuvial clay (avg. 15%). A thin (avg. 3 cm thick) litter layer occurs at the surface. A typical soil in this ET features an A/E/Bw-Bt/C/R horizonation. Diagnostic soil horizons include a thin ochric epipedon (avg. 7 cm thick), and a cambic (avg. 33 cm thick) or weak argillic horizon (avg. 52 cm thick). Cambic and argillic horizons were lacking in Entisols. One soil featured a mollic epipedon (34 cm thick). Particle size class was sandy-skeletal with one fragmental soil. Alfisols and clay-rich Mollisols,



including Typic Haplocryalfs [1] and Typic Argicryolls [1], may occur in this ET in pockets of finer-grained parent materials. These more developed soils were relatively low in coarse fragments (avg. 52%), and high in clay (avg. 28%). Soils in the PICOL/ARCO9, Como Family ET were typically Inceptisols, Entisols, and weak Alfisols, including Psammentic Haplocryalfs [1], Typic Haplustepts [1], Typic Eutrocryepts [1], Typic Ustorthents [1], and Typic Cryorthents [2].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Typic Eutrocryepts

Oi—0 to 1 cm: slightly decomposed plant material; abrupt wavy boundary.

Oe—1 to 2 cm: moderately decomposed plant material; clear wavy boundary.

A—2 to 3 cm: black (10YR 2/1) cobbly loam, dark grayish brown (10YR 4/2), dry; 48% sand; 12% clay; weak very fine subangular blocky structure; friable, slightly hard, moderately sticky, nonplastic; common fine roots and common very fine roots; common very fine and fine and common medium pores; 3% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 4% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 15% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.9; clear wavy boundary.

Bw1—3 to 25 cm: dark yellowish brown (10YR 4/4) extremely stony loam, pale brown (10YR 6/3), dry; 51% sand; 17% clay; weak fine subangular blocky structure, and weak very fine subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many medium roots and common coarse roots and common very coarse roots and common very fine roots; common fine and many medium and common coarse and common very coarse and common very fine pores; 19% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 21% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 34% nonflat subrounded indurated 76- to 250-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.9; clear wavy boundary.

Bw2—25 to 54 cm: brown (10YR 5/3) extremely bouldery coarse sandy loam, light gray (10YR 7/2), dry; 72% sand; 11% clay; weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 16% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 19% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 20% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 25% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; abrupt smooth boundary.

2C—54 to 90 cm: brown (7.5YR 4/4) bouldery loamy coarse sand, light brown (7.5YR 6/3), dry; 87% sand; 5% clay; single grain; loose, slightly sticky, nonplastic; common very fine and fine roots and few medium roots; common very fine and fine and few medium pores; 14% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 82% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.7; very abrupt smooth boundary.

2R—90 cm: bedrock.

Ecology

The PICOL/ARCO9, Como Family ET is characterized by small, slow-growing trees and limited regeneration. The lodgepole pines were stunted and tree cores revealed numerous tight growth rings, indicating long unproductive periods with minimal growth between years. The deep, sandy soils, high in rock fragments (avg. 75%) associated with the PICOL/ARCO9, Como Family ET are highly unproductive and drought stricken. Also, coarse-textured soils, such as those in the PICOL/ARCO9, Como Family ET, usually have low cation exchange capacities, which, when combined with a Udic moisture regime, can result in significant nutrient losses from the soil (Meurisse and others 1991).

Mollisols are most commonly associated with soils in grassland and sagebrush communities (Nimlos and Tomer

1982). However, a handful of Mollisols occurred under north-facing conifer stands, sites more typical of Alfisols, Inceptisols, or Entisols, including one sample site in the PICOL/ARCO9, Como Family ET that featured scattered quaking aspen in the overstory. The quaking aspen influence at this site is most likely associated with the most recent stand replacing burn and represents the early to middle stages of the transition between seral quaking aspen and mature lodgepole pine forest.

Succession

The successional status of the PICOL/ARCO9, Como Family ET is climax on unproductive sites and dominant seral on fine-grained soils (Pfister and Daubenmire 1975). This ET falls within the LP-2 (mature stands) post-fire successional stages of the "Persistent Lodgepole Pine Community Types" of Bradley and others (1992). Lodgepole pine is typically the only tree present at the site. Occasionally aspen will co-occur with lodgepole pine. After stand-replacing disturbance events, and in the absence of severe fire, a brief (10–20 years) herbaceous/shrub stage is followed by (1) a lodgepole pine seedling/ sapling stage (10–40 years), (2) pole-sized stage (40–150 years), (3) mature forest stage (150–300 years), and (4) overmature stage (>300 years), at which point the overstory begins to break up and an uneven-aged stand develops. At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. At stages 2 through 4, low to moderate fires thin stands while severe fires reset the successional pathway. The climax forest approximates an all-aged lodgepole pine stand.

In stands seral to subalpine fir, the successional pathway is very similar to that previously described, with the exception that subalpine fir seedlings are present in the understory of the mature forest stage (Bradley and others 1992). Subalpine fir seedlings may occur in the understory of the pole-sized stage if a low to moderate fire thins the stand providing openings in which subalpine fir may establish. Subalpine fir gradually gains dominance as individual lodgepole pines, removed by mountain pine beetle and dwarf mistletoe mortality, are replaced in the overstory by subalpine fir.

In stands where quaking aspen co-occurs with lodgepole pine, lodgepole pine seedlings and quaking aspen sprouts both establish during the initial herbaceous/shrub phase (Bradley and others 1992). Quaking aspen quickly overtops lodgepole pine seedlings during the seedling/sapling stage, restricting lodgepole pine to openings in the canopy where quaking aspen suckers are absent. At this stage, low to moderate fires favor lodgepole pine seedling establishment and quaking aspen sprouts by opening up the stand and stimulating root suckering of quaking aspen. In the absence of fire, the quaking aspen overstory eventually breaks up and an all-aged lodgepole pine forest develops. As the stand approaches climax, lodgepole pine drops out of the overstory and quaking aspen occasionally survives in small, emaciated patches. At extremely rocky sites, quaking aspen may remain in the overstory on boulder piles and in the crevices between rock outcrops.

Management considerations

The PICOL/ARCO9, Como Family ET is not suited for timber harvest due to its low productivity and the difficulty inherent in accessing the rocky terrain with logging equipment. Of more importance to forest managers are dwarf mistletoe infestations and mountain pine beetle epidemics. The degree of dwarf mistletoe infections in lodgepole pine stands in the Medicine Bow National Forest in southeastern Wyoming were shown to positively correlate to the age of the stand by Kipfmueller and Baker (1998). Periodic stand replacing burns help control dwarf mistletoe infections and result in healthy lodgepole pine forests.

These stands are at high risk of mountain pine beetle infestation under future climate warming scenarios. Managers concerned with mountain pine beetle epidemics should consider closely monitoring the PICOL/ARCO9, Como Family ET for signs of beetle activity. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control mountain pine beetles in lodgepole pine stands.

During the herbaceous stage, following severe fire, this ET may provide moderate amounts of forage. Russet buffaloberry is important during the initial stages of stand regeneration due to its ability to transform atmospheric nitrogen into biologically available forms. Forage production drops dramatically as stand age increases, with climax stands having little to no forage production.

Similar ecological types

Ecological Type 1

Type: Lodgepole pine/Oregon grape, Agneston Family ET

Floristic differences: The two types differ floristically in that PNV in the Como Family ET is the lodgepole pine/heartleaf arnica or lodgepole pine/common juniper community types, while PNV in the Agneston Family ET is lodgepole pine/Oregon grape community type.

Environmental differences: The two types differ in that the soils in the Como Family ET are typically moderately deep and deep Entisols and Inceptisols, while the soils in the Agneston Family Et are typically deep, clay-rich Alfisols. Also, the Como Family ET occurs on upper backslope and shoulder positions, while the Agneston Family ET occurs on lower backslope and footslope positions.

Table 77—Summary of environmental variables for the PICOL/ARCO9, Como Family ET.

General environment	**Average**	**Min**	**Max**
Elevation (m)	2,664	2,429	2,811
Slope (%)	21	15	24
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	627	547	675
Degree days	16,060	14,470	18,500
Frost-free days	19.6	18.8	20.8
Site water balance (mm/year)	-281	-350	-221
Average annual temperature (°C)	1.7	1.0	2.7
Total annual potential evapotranspiration (mm)	575	516	624
Summer radiation (KJ)	19,620	19,200	20,050
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	75	47	95
Clay (% in particle size control section)	15	7	30
pH (in particle size control section)	4.8	4.7	5.1
Available water capacity (mm/m)	38	8	87
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	5
Exposed bedrock	5	0	30
Gravel	2	0	5
Cobble	9	0	25
Stones	9	0	25
Boulders	2	0	5
Litter	34	15	60
Wood	14	5	25
Moss and lichen	4	0	18
Basal vegetation	21	10	35
Water	0	0	0

Table 78—Constancy/cover table for common plant species occurring in the PICOL/ARCO9, Como Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	33	15	70
Subominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	50	15	15	15
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	83	3	1	5
Seedlings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	83	1	1	3
PIFL2	*Pinus flexilis*	limber pine	50	2	1	3
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	common juniper	83	1	1	3
Forbs:						
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	9	1	20
CARO2	*Campanula rotundifolia*	harebell	50	1	1	1
COTR3	*Corallorrhiza trifida*	yellow coralroot	67	1	1	1
EUGL13	*Eucephalus glaucus*	gray aster	50	2	1	3
HITRG2	*Hieracium triste* var. *gracile*	slender hawkweed	67	1	1	1
ORSE	*Orthilia secunda*	sidebells wintergreen	50	1	1	1
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	50	1	1	1
Grasses:						
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	2	1	3
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	83	1	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 79—Stand characteristics for the PICOL/ARCO9, Como Family ET.

Species	Basal area		Diameter at breast height (DBH)		Trees per hectare	
	Average	Range	Average	Range	Average	Range
	---m²/ha---		*-------Centimeters-------*			
PICOL	34.4	6.9–52.8	18.5	7.6–41.1	1512	393–2,873
POTR5	18.4	—	10.9	8.1–13.5	2114	—

Species	Site tree averages		
	DBH	Height	Age
	Centimeters	*Meters*	*Years*
PICOL	22.1	14	96
POTR5	12.2	—	—

Lodgepole Pine/Ross' Sedge, Targhee Family Ecological Type

Pinus contorta var. *latifolia/Carex rossii*, Targhee Family Ecological Type

PICOL/CARO5, Targhee Family ET

N = 3

Distribution

The lodgepole pine/Ross' sedge, Targhee Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs in the area around Dickinson Park and the area south and east of Louis Lake. It is a component of map units 309L and 309A. To the south and east of Louis Lake, this ET occurs primarily on summits, shoulders, and backslopes of a network of diabasic gabbro dikes that have intruded into the Louis Lake Pluton. Near Dickinson Park, this ET occurs on shoulders, backslopes, and footslopes of low to moderate gradient mountain slopes in park-forest vegetation.

Environment

Aspect: North-northeast [1], south-southwest [1], west-southwest [1].

Landforms and Landscape Position: Diabasic gabbro dikes and mountain slopes. Summits, shoulders, backslopes, footslopes

Parent Materials: Residuum and/or colluvium.

In the area south and east of Louis Lake, parent materials were granodiorite of the Louis Lake Pluton or diabasic gabbro. Near Dickinson Park, parent materials were porphoritic quartz monzonite.

Bedrock: Granodiorite or porphoritic quartz monzonite.

In the area south and east of Louis Lake, bedrock was granodiorite of the Louis Lake Pluton. Near Dickinson Park bedrock was porphoritic quartz monzonite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 63 to 66 cm.

Additional environment data summaries are provided in Table 80.

Potential natural vegetation

On exposed summits, shoulders, and upper backslopes, this ET occupies the whitebark pine/Ross' sedge habitat type lodgepole pine phase (Steele and others 1983). On sheltered backslopes and footslopes, this ET occupies the subalpine fir/Ross' sedge or subalpine fir/heartleaf arnica habitat types. Whitebark pine or subalpine fir is the projected climax dominant tree species. Lodgepole pine is always present in the overstory. Early seral sites typically exhibit a smaller size structure and closed canopy layer (30-55% overstory cover). Later seral sites typically exhibit a more open overstory with higher cover of whitebark pine or subalpine fir, and lodgepole pine regeneration is often limited to scattered seedling and understory individuals. Whitebark pine or subalpine fir regeneration becomes more prolific with increasing stand age.

Common juniper and kinnikinnick may occur at very low abundance or shrubs may be completely lacking. The herbaceous layer is highly depauperate. Ross' sedge and Wheeler's bluegrass are the most common graminoids. Umber pussy-toes, ballhead sandwort, varileaf cinquefoil, and manyray goldenrod are the most common forbs. Summaries of species constancy/cover and stand characteristics are provided in Tables 81 and 82, respectively.

Soils

Soils on shoulders and summits in the PICOL/CARO5, Targhee Family ET are moderately deep with a low degree of soil development, high coarse fragments (67%), and little clay illuviation into subsurface soil horizons. A patchy litter layer (0 to 2 cm thick) occurs at the surface. A typical soil features an A/Bw/C/Cr horizonation. The Cr-horizon was composed of grus, a type of partially decomposed bedrock that has weathered to gravel-sized rock fragments. The grus was dense, prohibitive to root penetration, and extremely low in clay. Diagnostic soil horizons include an ochric epipedon (9 cm thick), a cambic horizon (22 cm thick), and paralithic contact (55 cm depth). Soils were loamy-skeletal, mixed Typic Eutrocryepts [1].

On backslopes and footslopes, soils in this ET were deep, moderate in clay (avg. 22%), and low to moderate in coarse fragments (avg. 41%). A thin organic horizon (avg. 1 cm thick) occurs at the surface. A typical soil features an A/Bt/C horizonation. Diagnostic soil horizons include an ochric epipedon (avg. 10 cm thick) and an argillic horizon (avg. 56 cm thick). Soils were fine-loamy and loamy-skeletal, Eutric Haplocryalfs [2].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed Typic Eutrocryepts

Oi—0 to 2 cm: slightly decomposed plant material; Even within the forested sections of this plot, the thin "Oi" is not apparent everywhere. On average, this plot is covered with approximately 2 cm of litter; abrupt smooth boundary.

A—2 to 9 cm: very dark gray (10YR 3/1) sandy loam, dark gray (10YR 4/1), dry; 69% sand; 8% clay; weak very fine granular structure, and weak fine subangular blocky structure; friable, slightly hard, nonsticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 14% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; clear wavy boundary.

Bw1—9 to 19 cm: dark brown (10YR 3/3) medium gravelly sandy loam, brown (10YR 5/3), dry; 77% sand; 15% clay; weak fine granular structure, and weak medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many medium roots and common coarse roots and many very fine roots; common fine and many medium and common coarse and many very fine pores; 21% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.1; clear wavy boundary.

Bw2—19 to 31 cm: brown (7.5YR 4/4) very gravelly sandy clay loam, light yellowish brown (10YR 6/4), dry; 77% sand; 21% clay; weak medium subangular blocky structure; very friable, soft, slightly sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 5% nonflat subrounded indurated 600- to 3000-mm unspecified fragments and 50% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; clear smooth boundary.

CB—31 to 55 cm: dark yellowish brown (10YR 4/4) extremely gravelly sandy loam, light yellowish brown (10YR 6/4), dry; 82% sand; 17% clay; weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 15% nonflat subrounded indurated 600- to 3000-mm unspecified fragments and 53% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.2; Gravel: 53% is paragravel. Texture is GRX-SL (borderline COSL).; gradual smooth boundary.

Cr—55 to 107 cm: extremely gravelly coarse sand; 97% sand; 2% clay; single grain; loose, nonsticky, nonplastic; 68% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; Gravel: 68% is paragravel. Colors dry and moist are variegated.

Ecology

Lodgepole pine is one of the first species to regenerate on coarse-grained substrates following severe forest fire throughout the Rocky Mountains. Along the eastern slope of the WRR, lodgepole pine forests may reach a stable state akin to what some might consider climax vegetation, especially on the Flathead and Tensleep Formations and on lower elevation glacial moraines. However, the successional status of lodgepole pine can be quite complex and depends on the specific topo-edaphic conditions at a site. The lodgepole pine in the PICOL/CARO5, Targhee Family ET is considered to fall within the dominant seral and/or persistent successional classes of Pfister and Daubenmire (1975). Dominant seral status occurs when lodgepole pine is able to maintain a dominant overstory position for one to two centuries. Shade tolerant species slowly gain a foothold as individual lodgepole pine die. Lodgepole pine is eventually phased out of the community as it is unable to reproduce in the understory. Persistent status occurs when lodgepole pine maintains dominance for extensive periods of time, usually as the result of periodic fires that kill shade tolerant species before they can achieve dominance. Shade tolerant species may occur as scattered individuals but fail to obtain overstory dominance. Persistent lodgepole pine forests are often considered in an extended seral state; however, the endpoint of succession is often difficult to surmise. Similar sites adjacent to the PICOL/CARO5, Targhee Family ET support whitebark pine or subalpine fir forests, providing clues as to the potential natural vegetation of the Targhee Family ET. Contrary to the ecological type concept, which is based on potential natural vegetation (Winthers et al. 2005), the Targhee Family ET is based on a seral vegetation type. However, the Targhee Family ET was considered significant enough in spatial extent and, given the persistent natural of lodgepole pine in these stands, temporal extent to be classified as a separate ecological type for use and management purposes.

Succession

The successional status of the PICOL/CARO5, Targhee Family ET is dominant seral (Pfister and Daubenmire, 1975). After a stand-replacing burn and in the absence of severe fire, a brief (10-20 years) herbaceous/shrub stage (A) is followed by a lodgepole pine seedling/ sapling stage

(B) and then by a pole-sized stage (C). The pole-sized stage is typically too dense for subalpine fir seedlings to gain a foothold; however, a low to moderate fire during the pole-sized stage thins the stand, providing openings in which subalpine fir may establish. In the absence of fire, the stand progresses to a mature forest with subalpine fir regeneration in the understory (D) and finally an over-mature stage (E), at which point the overstory begins to break up and an uneven-aged stand develops. Subalpine fir gradually gains dominance as individual lodgepole pines, removed by mountain pine beetle and dwarf mistletoe mortality, are replaced in the overstory by subalpine fir. At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. At stages 2 through 4, low to moderate fires thin stands while severe fires reset the successional pathway. The climax forest approximates an all-aged lodgepole pine stand.

Where lodgepole pine is seral to whitebark pine, post-fire succession begins with a brief herbaceous stage (A) in which Ross' sedge regenerates rapidly from underground rhizomes and quickly dominates the site. Immediately following the fire during the initial herbaceous stage, Clark's nutcrackers cache whitebark pine seeds across the burned area. The cones of lodgepole pine in this ET are typically non-serotinous, and regeneration of lodgepole pine is dependent on seeds from adjacent, unburned lodgepole pine. As lodgepole pine seeds gradually reach the site over the course of several years, an uneven-aged lodgepole and whitebark pine seedling/sapling stand (B) follows stage (A) (Bradley and others 1992). A fire of any intensity at stage (B) will completely reset the successional pathway. In the absence of fire, stage (B) is followed by an open, pole-sized lodgepole and whitebark pine stand (C), then by a mature lodgepole pine and whitebark pine stand (D), and eventually by a climax stand of mixed lodgepole and whitebark pine (E). Regeneration of lodgepole and whitebark pine at stage (E) is a continual and gradual process as gaps created in the forest canopy are slowly filled by seedlings of both species. Regeneration success tends to be greater for whitebark pine, which is slightly more shade tolerant than lodgepole pine. Low to moderate intensity fires at stages (C) through (E) will maintain the stand at each respective stage, while severe fires at stages (C) through (E) will completely reset the successional pathway.

Management considerations

The most important management consideration in these warm, lower elevation lodgepole pine forests is risk of mountain pine beetle infestations. Mountain pine beetles are favored by mild winters and warm, droughty summers—climatic factors responsible for epidemics (Howard 2002). Temperatures at low and mid-elevations have historically been most favorable for mountain pine beetle broods, and lodgepole pine forests within this elevation range are at higher risk of attack. Mountain pine beetle epidemics often begin in lower elevation lodgepole pine stands and move into upper elevation forests (Eggers 1990). Managers concerned with mountain pine beetle epidemics in upper elevation whitebark pine forests may consider monitoring these lower elevation lodgepole stands for signs of beetle activity. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control mountain pine beetles in lodgepole pine stands.

This ET is suited for timber harvest, especially on backslopes and footslopes, as it is moderately productive and the gentle terrain provides for easy access by logging equipment. Alexander (1986), Alexander and Edminster (1981), and Benson (1982) provided in-depth reviews of silivicultural techniques in lodgepole pine forests. During the herbaceous stage, directly following severe fire, this ET may provide moderate amounts of forage. However, forage production drops dramatically as stand age increases, with climax stands having little to no forage production.

Similar ecological types

Ecological Type 1

Type: Whitebark pine/Ross' sedge, Como Family ET

Floristic differences: The two types differ floristically in their successional status. The Como Family ET may represent potential natural vegetation of the Targhee Family ET on summits, shoulders, and upper backslopes in areas adjacent to Louis Lake.

Environmental differences: The two types are very similar environmentally.

Ecological Type 2

Type: Whitebark pine/Ross' sedge, Frisco Family ET

Floristic differences: The two types differ floristically in their successional status. The Frisco Family ET may represent potential natural vegetation of the Targhee Family ET on summits, shoulders, and upper backslopes in and around Dickinson Park.

Environmental differences: The two types are very similar environmentally.

Ecological Type 3

Type: Subalpine fir/grouse whortleberry, Marosa Family ET

Floristic differences: The two types differ floristically in their successional status. The subalpine fir/heartleaf arnica habitat type of the Marosa Family ET may represent potential natural vegetation of the Targhee Family ET on lower backslopes and footslopes.

Environmental differences: The Targhee Family ET occurs on granitic substrates, while the Marosa Family ET may occur on sandstone or granitic substrates. On granitic substrates, the two types are very similar. However, it is unknown whether the Targhee Family ET ccurs on sandstone.

Table 80—Summary of environmental variables for the PICOL/CARO5, Targhee Family ET.

General environment:	Average	Min	Max
Elevation (m)	2754	2665	2884
Slope (%)	5	3	8
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	649	634	663
Degree days	14850	13530	15750
Frost-free days	18.9	18.4	19.3
Site water balance (mm/year)	-259	-288	-206
Average annual temperature (°C)	1.2	0.7	1.5
Total annual potential evapotranspiration (mm)	570	519	612
Summer radiation (KJ)	20520	20220	20850
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	50	32	67
Clay (% in particle size control section)	17	8	24
pH (in particle size control section)	5.4	5.2	5.6
Available water capacity (mm/m)	63	41	79
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	1	0	2
Exposed bedrock	0	0	0
Gravel	1	0	3
Cobble	1	0	2
Stones	1	0	2
Boulders	1	0	5
Litter	71	68	75
Wood	8	5	15
Moss and lichen	1	0	2
Basal vegetation	13	10	15
Water	0	0	0

Table 81—Constancy/cover table for common plant species occurring in the PICOL/CARO5, Targhee Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	23	15	35
Subdominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	13	5	25
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	67	4	3	5
Seedlings:						
PIAL	*Pinus albicaulis*	whitebark pine	67	3	1	5
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	5	1	10
Forbs:						
ANUM	*Antennaria umbrinella*	umber pussy-toes	100	1	1	1
ARCO9	*Arnica cordifolia*	heartleaf arnica	67	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	100	1	1	1
LUAR3	*Lupinus argenteus*	silvery lupine	67	1	1	1
OSDE	*Osmorhiza depauperata*	blunt-fruited sweet-cicely	67	1	1	1
PODI2	*Potentilla diversifolia*	varileaf cinquefoil	100	1	1	1
SOMUS	*Solidago multiradiata* var. *scopulorum*	manyray goldenrod	100	2	1	3
Grasses:						
ELEL5	*Elymus elymoides*	squirreltail	67	1	1	1
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	3	1	5
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	100	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 82—Stand characteristics for the PICOL/CARO5, Targhee Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------Centimeters-------			
PICOL	32.1	23.0–36.7	24.9	13.5–42.2	741	593–889

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
	28.7	11	148

Lodgepole Pine Series, Corbly Family Ecological Type

Pinus contorta var. *latifolia* Series, Corbly Family Ecological Type

PICOL Series, Corbly Family ET

N = 4

Distribution

The lodgepole pine series, Corbly Family Ecological Type, occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs in the South Pass Granite-Greenstone Belt and is a component of join unit 106D.

Environment

Aspect: North-northeast [1], North-northwest [1], southeast [2].

Landforms and Landscape Position: Lower backslopes and footslopes. Topographic depressions.

Parent Materials: Residuum. Granodiorite-amphibolite gneiss, granodiorite-graywacke gneiss, migmatite, and grantite.

Bedrock: This ET was located in the South Pass Greenstone Belt and includes a complex of metasedimentary rocks that form the Gneiss Belt, a border zone of contact metamorphism within the Greenstone Belt that features interlayered migmatite, graywacke gneiss, amphibolite, granite, and granodiorite (Hausel 1988).

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation ranges from 59 to 60 cm.

Additional environment data summaries are provided in Table 83.

Potential natural vegetation

The potential natural vegetation of this ecological type contains a number of different lodgepole pine communities, including lodgepole pine/Oregon grape, lodgepole pine/russet buffaloberry, lodgepole pine/heartleaf arnica, and lodgepole pine/Ross' sedge (Steele and others 1983). Lodgepole pine dominates the tree canopy and features strong regeneration in the understory. Limber pine co-occurs with lodgepole pine in the overstory with limited regeneration. Quaking aspen is commonly found scattered throughout the understory. Oregon grape is the more common shrub species. Common forbs include narrow-leaf collomia, small-flowered blue-eyed mary, and silvery lupine. Wheeler's bluegrass and Ross' sedge always occur and are sometimes joined by Idaho fescue and little ricegrass. Summaries of species constancy/cover and stand characteristics are provided in Tables 84 and 85, respectively.

Soils

Soils in the PICO Series, Corbly Family ET were moderately deep and deep with a low degree of soil development, moderately high (avg. 55%) in coarse fragments (particularly gravels), and low in clay (avg. 12%). A thin (avg. 2 cm thick) litter layer typically occurs at the surface. A typical soil features an A/Bw/BC-C/Cr-R horizonation. Diagnostic soil horizons include a mollic (avg. 26 cm thick) or ochric (avg. 14 cm thick) epipedon, a cambic horizon (avg. 21 cm thick), and lithic or paralithic contact (in moderately deep soils). One soil featured an ochric epipedon (15 cm thick), and a weakly developed argillic horizon (19 cm thick) over a gravelly C-horizon. Entisols lacked both a cambic and argillic horizon. Particle size class was primarily sandy-skeletal with one soil of the loamy-skeletal class. The soils included Entisols and weak Mollisols and

Alfisols. Soils were Inceptic Haplustalfs, Typic Haplustolls, Entic Haplustolls, and Typic Ustorthents.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Entic Haplustolls

Oi—0 to 1 cm: slightly decomposed plant material; abrupt smooth boundary.

Oe—1 to 2 cm: moderately decomposed plant material; clear smooth boundary.

A—2 to 12 cm: grayish brown (10YR 5/2) channery very fine sandy loam, very dark grayish brown (10YR 3/2) and very dark brown (10YR 2/2), moist; 68% sand; 15% clay; weak medium subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and many very fine roots; common fine and common medium and common coarse and many very fine pores; 6% flat angular indurated 380- to 600-mm unspecified fragments and 12% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 14% flat angular indurated 150- to 380-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; clear wavy boundary.

BA—12 to 31 cm: brown (10YR 5/3) very flaggy fine sandy loam, very dark grayish brown (10YR 3/2), moist; 71% sand; 17% clay; weak medium subangular blocky structure, and moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common coarse roots and common very fine roots; common fine and common medium and common coarse and common very fine pores; 11% flat angular indurated 150- to 380-mm unspecified fragments and 15% flat angular indurated 380- to 600-mm unspecified fragments and 21% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.3; clear wavy boundary.

Bw—31 to 42 cm: pale brown (10YR 6/3) extremely bouldery sandy loam, brown (10YR 4/3), moist; 79% sand; 13% clay; weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common medium roots and common very fine roots; common medium and common very fine pores; 30% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 55% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; very strongly acid, pH 5.0; clear wavy boundary.

2C—42 to 51 cm: light yellowish brown (10YR 6/4) extremely bouldery loamy sand, yellowish brown (10YR 5/4), moist; 80% sand; 7% clay; massive; very friable, soft, nonsticky, nonplastic; common medium roots and common very fine roots; common medium and common very fine pores; 31% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 50% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; very strongly acid, pH 4.8; clear wavy boundary.

2R—51 cm: bedrock.

Ecology

The PICOL Series, Corbly Family ET was characterized by uneven-aged stands of lodgepole pine and moderately deep and deep, coarse-textured soils. Many of these sites were logged in the early Twentieth Century and the trees were used as railroad ties. Inspection of old tree stumps revealed that many of these sites were dominated by Douglas-fir in the past. However, Douglas-fir seedlings were rarely encountered in the understory of the sample stands. These sites may have been marginal Douglas-fir habitat prior timber harvest in the early Twentieth Century. Changes in micro-climate and soil nutrient status related to timber harvest may have resulted in a change in vegetative potential at these sites. Coarse-textured soils, such as those in the PICOL Series, Corbly Family ET, usually have low cation exchange capacities, which, when combined with a Udic moisture regime, can result in significant nutrient losses from the soil, especially when coupled with a loss of vegetation (Meurisse and others 1991). Despain (1973) cited the high (relative to lodgepole pine) nutrient requirements of Douglas-fir as a likely reason for the absence of Douglas-fir on sandy soils derived from granite and sandstone parent materials in the Bighorn Mountains of north-central Wyoming. Sandy soils tend to have a lower supply of nutrients in the original parent material and increased leaching, resulting in more nutrient poor conditions than finer soils (Anderson 1988). Water stress may also play a role in the absence of Douglas-fir on the metasedimentary and granitic soils of this ET.

Mollisols are most commonly associated with soils in grassland and sagebrush communities (Nimlos and Tomer 1982). However, a handful of Mollisols occurred under north-facing conifer stands, sites more typical of Alfisols, including two sample sites in the PICOL Series, Corbly Family ET. Quaking aspen is seral to lodgepole pine in this ET following forest fire, and the early seral stages of these forested stands feature vigorous quaking aspen resprouts. Quaking aspen leaves, which have high concentrations of cations and decompose quickly due to a low carbon to nitrogen ratio, contribute strongly to the development of thick, dark, carbon-rich surface horizons with relatively high pH (typically >6.0) (Cryer and Murray 1992; Howard 1996; Legare and others 2005).

Succession

The successional status of the PICOL Series, Corbly Family ET is climax on these unproductive sites (Pfister and Daubenmire 1975). This ET falls within the LP-2 (mature stands) post-fire successional stages of the "Persistent Lodgepole Pine Community Types" of Bradley and others

(1992). Lodgepole pine typically co-occurs with quaking aspen and limber pine. Following a stand-replacing burn, a brief (10–20 years) herbaceous/shrub stage (A) is followed by a lodgepole pine, limber pine, and quaking aspen seedling/sapling stage (B) (10–40 years). At the herbaceous/shrub and seedling/sapling stages, a fire of any intensity will reset the successional pathway. In the absence of fire, quaking aspen quickly overtops lodgepole and limber pine seedlings during the seedling/sapling stage, restricting lodgepole and limber pine to openings in the canopy where quaking aspen suckers are absent. At stage (B), low to moderate fires favor lodgepole pine seedling establishment and quaking aspen sprouts by opening up the stand and stimulating root suckering of quaking aspen.

In the continued absence of fire, a pole-sized stage develops (C) (40–150 years), during which the quaking aspen overstory begins to break up and an all-aged lodgepole pine forest develops (D) (150–300 years). As the stand approaches climax, quaking aspen drops out of the overstory and occasionally survives in small, emaciated patches. At extremely rocky sites, quaking aspen may remain in the overstory on boulder piles and in the crevices between rock outcrops. At stages (C) and (D), low to moderate fires thin stands, while severe fires reset the successional pathway.

Management considerations

The PICOL Series, Corbly Family ET shows promise for timber management. The location of this ET on gently undulating slopes (avg. 19%) provides for easy access of logging equipment. Since forested stands of this ecological type tend to be uneven-aged, timber harvest methods that select for mature trees, including single tree and group selection, should be used shortly after the first cohort of tree reaches maturity. Single tree and group selection techniques will also help mitigate changes in micro-climate at the forest floor that can negatively influence tree seedling survival. Low intensity broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe, open serotinous cones, remove duff, and prepare mineral soil for lodgepole pine regeneration (Anderson 2003). Fire in lodgepole pine stands often results in a pulse of biologically available nitrogen in the soils (Giardina and Rhoades 2001) and increased forage production for big game in the years shortly after timber harvest. Mountain pine beetle epidemics often begin in lower elevation lodgepole pine stands and move into upper elevation forests (Eggers 1990). Managers concerned with mountain pine beetle epidemics in whitebark pine forests may consider monitoring the PICOL Series, Corbly Family ET for signs of beetle activity. Silvicultural techniques and prescribed fire can be used to treat these stands for mountain pine beetle infestations. Please refer to Amman and others (1977), Cole and others (1983), and Klein (1978) for more information on the use of silvicultural techniques in the control mountain pine beetles in lodgepole pine stands.

Forage and browse production is high during the initial stages of this ecological type. Russet buffaloberry and silvery lupine are important during the initial stages of stand regeneration due to their ability to transform atmospheric nitrogen into biologically available forms. Forage production drops continually as stand age increases, and Oregon grape may be the only species with appreciable forage value in climax stands. However, these stands are located directly adjacent to mountain big sagebrush and grassland communities and provide important thermal and hiding cover for deer and elk.

Similar ecological types

Ecological Type 1

Type: NONE

Table 83—Summary of environmental variables for the PICOL Series, Corbly Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,594	2,581	2,618
Slope (%)	19	12	24
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	597	589	602
Degree days	16,630	16,480	16,910
Frost-free days	19.8	19.7	19.9
Site water balance (mm/year)	-321	-342	-290
Average annual temperature (°C)	1.9	1.8	2.0
Total annual potential evapotranspiration (mm)	623	606	639
Summer radiation (KJ)	20,170	19,710	20,550
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	55	33	75
Clay (% in particle size control section)	12	6	23
pH (in particle size control section)	5.2	5.1	5.4
Available water capacity (mm/m)	39	30	57
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	0	5
Exposed bedrock	0	0	0
Gravel	3	0	10
Cobble	5	0	15
Stones	3	0	10
Boulders	1	0	2
Litter	39	25	55
Wood	21	20	25
Moss and lichen	1	0	2
Basal vegetation	24	15	45
Water	0	0	0

Table 85—Stand characteristics for the PICOL Series, Corbly Family ET.

	Basal area		**Diameter at breast height (DBH)**		**Trees per hectare**	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		*-------Centimeters-------*			
PICOL	20.2	11.5–27.6	20.1	10.9–28.2	761	546–1,057
PIFL2	2.3	—	18.3	—	86	—
POTR5	9.2	—	16.5	5.3–27.9	1,420	—
PSMEG	2.3	—	23.6	14.2–32.3	74	27–143

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PICOL	20.3	14	85
PIFL2	18.3	11	83
POTR5	9.9	7	—
PSMEG	23.6	16	73

Table 84—Constancy/cover table for common plant species occurring in the PICOL Series, Corbly Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	100	21	10	35
Subominant overstory trees:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	10	10	10
PIFL2	*Pinus flexilis*	limber pine	75	4	3	5
PSMEG	*Pseudotsuga menziesii* var. *glauca*	Rocky Mountain Douglas-fir	50	2	1	3
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	8	5	10
PIFL2	*Pinus flexilis*	limber pine	50	1	1	1
POTR5	*Populus tremuloides*	quaking aspen	50	5	5	5
Seedlings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	2	1	5
PIFL2	*Pinus flexilis*	limber pine	75	1	1	1
POTR5	*Populus tremuloides*	quaking aspen	75	2	1	5
Shrubs:						
MARE11	*Mahonia repens*	Oregon grape	75	4	1	10
PUTR2	*Purshia tridentata*	antelope bitter-brush	50	2	1	3
Forbs:						
ANUM	*Antennaria umbrinella*	umber pussy-toes	50	2	1	3
ARCO9	*Arnica cordifolia*	heartleaf arnica	50	4	3	5
COLI2	*Collomia linearis*	narrow-leaf collomia	75	1	1	1
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	75	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	50	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	50	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	50	1	1	1
LUAR3	*Lupinus argenteus*	silvery lupine	75	1	1	1
PHMU3	*Phlox multiflora*	many-flowered phlox	50	1	1	1
SEIN2	*Senecio integerrimus*	lambstongue ragwort	50	2	1	3
TAOF	*Taraxacum officinale*	common dandelion	50	1	1	1
Grasses:						
FEID	*Festuca idahoensis*	Idaho fescue	75	2	1	5
PIEX3	*Piptatherum exiguum*	little ricegrass	75	3	1	7
POWH2	*Poa wheeleri*	Wheeler's bluegrass	100	4	1	7
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	100	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Miscellaneous Lodgepole Pine Types

Lodgepole Pine/Grouse Whortleberry, Telcher Family Ecological Type

Pinus contorta var. *latifolia/Vaccinium scoparium*, Telcher Family Ecological Type

PICOL/VASC, Telcher Family ET

N = 2

The lodgepole pine/grouse whortleberry, Telcher Family Ecological Type occurs along the eastern flank of the WRR in the dry, mid-elevation, sedimentary mountains ecoregion of Chapman and others (2004). It is a component of map unit 43LF. This ET occurs on low gradient (avg. 11%) backslopes, footslopes, and toeslopes of the Flathead Formation. Soils were moderately deep and deep, formed from sandstone residuum, low in rock fragments (18%), and moderately high in clay (17%). Soils were fine-loamy, Mollic Haplocryalfs and coarse-loamy, Ustic Eutrocryepts. Potential natural vegetation of this ET is the lodgepole pine/grouse whortleberry habitat type (Steele and others 1983). Lodgepole pine dominates all canopy layers and is found successfully reproducing in the understory. Occasional whitebark pine seedlings may occur. Quaking aspen is always found scattered throughout this community as straggling isolated individuals. Grouse whortleberry is the dominant shrub species, usually occurring in irregularly spaced, isolated patches. Other shrub species occurring at low abundance include russet buffaloberry and Oregon grape. Important herbaceous species include heartleaf arnica, sidebells wintergreen, northern bedstraw, Virginia strawberry, Ross' sedge, and Wheeler's bluegrass. Woodland pinedrops, a saprophytic species that parasitizes the roots of lodgepole pine, sometimes occurs in this type. Quaking aspen is a major seral species in this ecological type, and provides abundant browse for wild ungulates in early seral stands. This ET is quite productive, and is suitable for timber harvest. Broadcast burning of slash following timber harvest operations will effectively control dwarf mistletoe, open serotinous cones on downed branches, remove duff, prepare mineral soil for lodgepole pine regeneration, and improve quaking aspen regeneration. The subalpine fir/grouse whortleberry, Marosa Family ET, when it occurs on sandstone, is similar environmentally to lodgepole pine/grouse whortleberry, Telcher Family Ecological Type. However, the PNV of the Marosa Family ET is subalpine fir, while the PNV of the Telcher Family ET is lodgepole pine.

Lodgepole Pine/Ross' Sedge, Stecum Family Ecological Type

Pinus contorta var. *latifolia/Carex rossii*, Stecum Family Ecological Type

PICOL/CARO5, Stecum Family ET

N = 1

The lodgepole pine/Ross' sedge, Stecum Family Ecological Type occurs along the southern WRR within the granitic subalpine zone of Chapman and others (2004). This ET occurs in between Frye Lake and Meyer Lookout and just to the west of the South Pass Granite-Greenstone Belt. It is a component of map unit 317L. This ET occurs on summits and shoulders of mountains formed from foliated outcrops of Louis Lake Granodiorite. Soils were generally shallow to moderately deep, sandy, high in rock fragments (84%), and low in clay (6%). Soils were sandy-skeletal Typic Cryorthents. Potential natural vegetation of this ET is the lodgepole pine/Ross' sedge habitat type (Steele and others 1983). Lodgepole and limber pine occur in all canopy layers forming an open-canopy forest. Lodgepole pine seedlings are most prolific in the understory, co-occurring with limber pine and Douglas-fir seedlings. Scattered Utah snowberry, common juniper, mountain big sagebrush, and antelope bitterbrush attest to the warm, sunny conditions at these sites. An erosion pavement of coarse sands and gravels dominates the soil surface in the openings between trees, while a discontinuous litter layer occurs beneath forested patches. The sparse herbaceous layer is surprisingly species rich, including Ross' sedge, rosy pussy-toes, many-flowered phlox, gray aster, spiny milkvetch, spiked ipomopsis, goosefoot violet, nineleaf biscuitroot, sulphur-flower buckwheat, little ricegrass, and Wheeler's bluegrass. This ET is extremely unproductive and is not suited for timber harvest. Off-road vehicle trails are not recommended in this ET as the sandy soils with low vegetative cover are easily eroded. The ET differs from other lodgepole pine Ecological Types in that it occurs exclusively in map unit 317L in the foliated outcrops of Louis Lake Granodiorite located just to the west of the South Pass Granite-Greenstone Belt.

Quaking Aspen Series

Principal Species Descriptions

Quaking Aspen

Populus tremuloides Michx.

The most widely distributed tree in North America, quaking aspen occurs continuously from Alaska, southeast across all Canadian Provinces, and into the north central and northeastern United States, including Minnesota, eastern Iowa, Wisconsin, northern Illinois, Michigan, northern Indiana, Ohio, Pennsylvania, New Jersey, New York, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, and Maine (Howard 1996; USGS 1999; USDA NRCS 2007b). Quaking aspen occurs to the southeast in mountainous regions of Delaware, Maryland, West Virginia, Virginia, and North Carolina and in scattered counties across Missouri and Arkansas (USDA NRCS 2007b). In the western United States, the distribution of quaking aspen is more or less continuous along the Rocky Mountains from northern Idaho and western Montana, south through Wyoming, Utah, Colorado, and northern New Mexico, and in the Pacific Northwest along the Cascade Ranges of Washington and Oregon and into the Sierra Nevada Mountains of California (USGS 1999). Scattered populations occur across mountain ranges of eastern Montana, Nevada, Arizona, and southern New Mexico. Disjunct populations occur in North and South Dakota, Nebraska, western Texas, and northern and central Mexico.

Across western North America, the topographic distribution of quaking aspen is strongly tied to latitude. Quaking aspen is one of the most northerly tree species and occurs in the southern reaches of the permafrost zone at elevations less than 910 m on south- and southwest-facing slopes where permafrost is locally absent (Howard 1996). Quaking aspen at its southern geographic limits is restricted to riparian zones and moist north-facing slopes at upper elevations. Between these two extremes, quaking aspen may occur on a variety of slope aspects so long as sites receive sufficient soil moisture. Quaking aspen is tolerant of a wide range of temperatures, such as is in Montana where temperatures range from as low as -57 ºC in January to a summer high of 41 ºC (Perala 1990). In the central Rocky Mountains, the lower altitudinal limit of quaking aspen strongly coincides with mean annual temperatures of approximately 7 ºC.

In the arid central and southern Rocky Mountains, soil moisture is the most important factor limiting the distribution of quaking aspen. Quaking aspen is limited to environments where precipitation exceeds evapotranspiration, or in localized topographic depressions where groundwater mitigates the effects of summer drought. The elevation of quaking aspen ranges between 1,829 and 2,926 m in Wyoming, 1,829 and 2,500 m in southeastern Idaho, 2,100 and 3,350 m in Colorado, 2,280 and 3,350 m in Utah, and 1,980 and 3,050 m in New Mexico and Arizona (Mueggler 1988; Powell 1988; Perala 1990; Svalberg and others 1997). In Nevada, quaking aspen ranges from 1,981 to 2,347 m in the northern part of the state, 2438 to 2957 m in the southern part of the state, and as low as 1,535 m in riparian zones (Manning and Padgett 1995; Mueggler 1988). In the Black Hills of South Dakota, quaking aspen is most prevalent between 1,219 and 1,902 m (Hoffman and Alexander 1987).

Quaking aspen occurs on a variety of soil types but is most productive on well drained to moderately well drained, deep loamy sands to heavy clay soils with high organic matter and nutrient content (Perala 1990). On extremely rocky sites, quaking aspen is found stunted and gnarled growing between boulders. Although quaking aspen is intolerant of long-term soil saturation, it is commonly found in riparian zones on streambanks, terraces, and floodplains with seasonally high water tables. Quaking aspen is found on soils derived from all major rock types, including igneous, metamorphic, and sedimentary; however, it is most productive on soils formed from basic igneous rock (basalt, andesite) or neutral to calcareous shales and limestones. Quaking aspen soils commonly have a thick, inky-black, carbon-rich surface horizon and relatively high pH (typically >6.0) that develops through the decomposition of fallen aspen leaves, which have high concentrations of cations and decompose quickly due to a low carbon to nitrogen ratio (Cryer and Murray 1992; Howard 1996; Legare and others 2005).

Quaking aspen is a small- to medium-sized tree that is typically less than 15 m tall and 40 cm in diameter with thin bark and a relatively shallow root system (Howard 1996). In the western United States, quaking aspen regenerates most often by sprouting of root suckers, often forming large clones connected to a central root system. In fact, the largest organism on Earth is an aspen clone located in Utah that encompasses an area of approximately 17 ha and supports 47,000 stems. Individual clones are typically less than 0.5 ha to several ha in size and either male or female, or occasionally both. Sprouting is controlled by the hormones auxin, which suppresses sprouting and maintains apical dominance, and cytokinin, which initiates sprouting following stem damage or mortality of the apical meristem. Sexual reproduction of quaking aspen occurs in the Rocky Mountains, perhaps more commonly than has previously been thought (Howard 1996). Flowering begins at two to three years of age; however, large seed crops are not produced until 10 to 20 years, with maximum seed production between 50 and 70 years (Perala 1990). Flowering, which is triggered by sustained temperatures above 12 ºC, occurs in May or June before the leaves have fully expanded. However, the timing of flowering and leaf expansion is highly variable owing to inter-sexual and inter-clonal variation. Pollination is by wind, and seeds ripen between four and six weeks after flowering begins. The tiny seeds, surrounded by white silky hairs, are wind and water dispersed and can be carried many kilometers from the parent tree.

Germination and seedling survival are strongly dependent on the type of seedbed, moisture, and temperature conditions, including bare mineral soil (especially fire exposed mineral soil), continuous soil moisture throughout the growing season, and optimal temperature conditions between 5 and 25 ºC (Howard 1996). At optimal sites, seedlings may reach 15 to 61 cm in height with root growth to 18 to 25 cm deep within the first year. Quaking aspen is intolerant of shade and is seral to conifers in many upland sites throughout the Rocky Mountains. However, quaking aspen may attain topo-edaphic climax in moist, topographic depressions and along riparian zones.

Quaking aspen is highly adapted to fire (Howard 1996). Adaptations include thin bark, profuse root sprouting following top kill, and the ability to self-thin. Additionally, the extensive clonal root system allows sprouts to extract water, nutrients, and photosynthate, promoting rapid sprout growth immediately following a fire. The existence of a massive root system allows quaking aspen to quickly outcompete conifers attempting to develop from seed. Small diameter aspen are normally top-killed by even low severity surface fires. Older, larger diameter quaking aspen have developed thicker bark on the lower stem and are more resistant to low severity fires. However, moderate intensity burns usually top kill all size classes of quaking aspen. Periodic forest fire is a key factor in maintaining healthy, even-aged quaking aspen stands in the Rocky Mountains. Fire suppression can lead to decadent, diseased aspen stands with little to no regeneration. Fire frequencies of 100 to 300 years help maintain most seral quaking aspen stands (Bradley and others 1992).

Prescribed burning is an excellent means of revitalizing decadent aspen stands and promoting new quaking aspen growth (Howard 1996). Clear-cutting and bulldozing may be used when prescribed burning is not feasible. However, the use of heavy machinery, when applied inappropriately, can cause soil compaction, extensive damage to quaking aspen roots, and increased susceptibility to pathogens. Slash removal will increase the density of quaking aspen sprouts following mechanical removal treatments by increasing the amount of sunlight in the understory. Herbicide treatments that kill aspen stems without killing the root system are an effective means of stimulating regeneration by root suckering (Schier and others 1985). Jones and Sheppard (1985) provided a comprehensive review of silivicultural techniques in aspen stands, including thinning, rotations, and harvesting. Quaking aspen is well suited for use in restoration and rehabilitation projects in disturbed sites, including riparian zones, mine spoils, and damage due to road construction (Howard 1996). Schier and others (1985) provided detailed information regarding artificial regeneration in quaking aspen.

Quaking aspen mortality results from a combination of both direct physical damage and disease (Perala 1990). Seedlings are commonly girdled and killed by bark-eating mammals, including meadow voles and snowshoe hares. Wild ungulate browsing and antler rubbing can cause severe stem damage and loss of seedling vigor. Elk and moose, attempting to reach the tender inner bark, can remove large areas of bark from larger stems, providing a vector for disease. Heavy browsing pressure from both domestic and wild ungulates that leads to serious reductions in stem density and severe root damage due to trampling can result in the eventual disappearance of affected aspen stands. Lastly, recreationists innocently scratching their initials into the trunk of an aspen can cause increased susceptibility to disease agents and death in as little as 10 to 20 years.

Leaf spot and shoot blight is a disease caused by *Marssonina populi* and can result in severe defoliation, with repeated infections causing mortality (Perala 1990). Less serious is the leaf rust fungi, *Melampsora* spp., which leads to leaf discoloration, limited leaf mortality, and premature leaf drop. A number of bacteria and fungi result in stem, heart, butt, and root rot, which reduce vigor and usable log volume. Of the stem and heart rots, *Phellinus tremulae* and *Fomes igniarius* are the most notorious (Hinds 1985). Stem cankers are sometimes mortal but more often lead to a loss of usable log volume. Species causing stem cankers often infect quaking aspen through trunk wounds and insect vectors.

Insects that damage quaking aspen include defoliators, wood boring, and sucking insects. Defoliators include moths, butterflies, and beetles (Perala 1990). Defoliators generally lead to defoliation over broad spatial areas, last two to three years and result in significant growth loss. Wood boring insects include long horned beetles (Cerambycidae) and metallic borers (Buprestidea). Woodborers tunnel into the bole, often developing extensive galleries and sometimes girdling individual stems. Woodborers weaken stems, degrade wood, and lead to increased susceptibility to disease and stem breakage. Sucking insects, which typically cause minimal damage, include aphids and leaf hoppers. Hinds (1985) and Perala (1990) provided extensive reviews of insect and disease agents of quaking aspen.

Quaking aspen forests provide incredibly important habitat for a number of birds and mammals (Howard 1996). Quaking aspen is highly palatable to all browsing livestock and wildlife species. Utilization of quaking aspen by browsing ungulates, including elk, moose, mule and white-tailed deer, domestic sheep, and cattle, is highest at early stages when stem density is highest, and stems are still within reach (≤five years). Quaking aspen is browsed throughout the year but is especially important in fall and winter when quaking aspen has relatively high protein levels compared with other browse species. Black bears will climb quaking aspen trees and feed on buds, leaves, and catkins (DeByle 1985). Lagomorphs, including rabbits and hares, and pikas feed on quaking aspen buds, twigs, and bark. Small mammals, including mice, voles, and shrews, feed on quaking aspen bark. Quaking aspen is an important food source and construction material for beavers.

Across the western United States, quaking aspen and mixed conifer-aspen forests provide nesting, feeding, and breeding habitat for an incredible number of bird species, including ground, shrub, canopy, and cavity nesting birds, raptors, and game birds (DeByle 1985). Cavity nesting birds are strongly tied to mature aspen forests for nesting sites, where cavities are excavated from aspen stems suffering from heart rot. The soft, punky heartwood of diseased aspen is easily hollowed out by strong excavators, including woodpeckers and sapsuckers, to form nesting cavities. The nesting cavities are used primarily by strong excavators and secondarily by weak and non-excavating cavity nesting birds, bats, owls, and occasionally northern flying squirrels (DeByle 1985; Dobkin and others 1995; Kalcounis and Brigham 1998). Of the game birds, ruffed grouse are perhaps most strongly tied to quaking aspen forest in the western United States. A wealth of literature regarding the importance of quaking aspen to wildlife is available. DeByle (1985) and Howard (1996) provided extensive reviews of quaking aspen and wildlife.

Quaking Aspen/Sticky Purple Geranium, Bullflat Family Ecological Type

Populus tremuloides/*Geranium viscosissimum*, Bullflat Family Ecological Type

POTR5/GEVI2, Bullflat Family ET

N = 8

Distribution

The quaking aspen/sticky purple geranium, Bullflat Family Ecological Type occurs in the northern and southern study areas within the dry mid-elevation sedimentary mountains and granitic subalpine zone ecoregions of Chapman and others (2004). It is a component of map units 15L, 43L, 44L, and 402L.

Environment

Aspect: East-northeast [1], east-southeast [1], north [2], northeast [1], north-northeast [1], north-northwest [1], northwest [1].

Landforms and Landscape Position: Landslide deposits, slumps, and seeps. Backslopes, footslopes, and toeslopes.

This ET occurs in topographic depressions where moisture accumulates, including nivation hollows and slumps, on limestone and shale slopes, and along riparian corridors. At toeslope positions, near the contact between the Gros Ventre and Flathead Formations, this ET occurs in narrow (<50 m), linear corridors, while on limestone and shale backslopes of low (5%) to moderate (25%) slope gradients, this ET forms small (1 ha) to large (20 ha) stands. On backslope and footslope positions such as the north slope of Indian Ridge, the occurrence and extent of this ET often corresponds with areas that have experienced mass wasting events, including landslides and slumps.

Parent Materials: Alluvium and colluvium.

In riparian areas, parent materials tend to be igneous or sedimentary alluvium or a mixture of igneous and sedimentary alluvium. On a seepy slope located on the south face of Fairfield Hill, this ET occurs on the Sinks Canyon moraine in granitic glacial till of Sacagawea Ridge age (600–770 Ka) (Dahms 2004b). On backslopes, parent materials were typically mixed sedimentary colluvium, including Madison or Gallatin Limestone, Bighorn Dolomite, or Gros Ventre Shale.

Bedrock: Granodiorite of the Louis Lake Pluton, Flathead Sandstone, Gros Ventre Shale, Bighorn Dolomite, or Gallatin Limestone.

Climate: Frigid temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 51 to 58 cm.

Additional environment data summaries are provided in Table 86.

Potential natural vegetation

The potential natural vegetation of this ET is the quaking aspen/sticky purple geranium habitat type. However, quaking aspen communities represent a topoedaphic climax along the eastern flank of the WRR. A decrease in soil moisture and/or a change in soil chemistry at these sites lends toward the predominance of conifiers in the overstory, to the detriment of quaking aspen.

Quaking aspen occurs in all canopy layers with vigorous regeneration from root suckers. Various conifer seedlings occur in the understory with limited abundance and vigor, including limber pine, Douglas-fir, and lodgepole pine. Woods rose, russet buffaloberry, common juniper, and Oregon grape are shrub species commonly found in this ecological type. Shrubby cinquefoil and twinberry honeysuckle are indicative of more mesic microsites. Scouler's willow and Sitka alder are common when this ET occurs in riparian corridors.

The herbaceous layer is characteristically species rich with 100% foliar cover of forbs and graminoids. An abundance (>5%) of sticky geranium and/or false Solomon's seal are indicative of this habitat type. Common herbaceous species include Colorado blue columbine, heartleaf arnica, northern bedstraw, western yarrow, slender cinquefoil, western meadowrue, and spike trisetum. Less common forbs include longhorn steer's-head and baneberry. Field and scouringrush horsetails may be found in riparian corridors. Nodding helianthella, Kentucky bluegrass, tall fescue, and duncecap larkspur are species indicative of disturbance by cattle grazing. Summaries of species constancy/cover and stand characteristics are provided in Tables 87 and 88, respectively.

Soils

Soils in the POTR5/GEVI2, Bullflat Family ET are deep with a high degree of soil development, low to moderate coarse fragments (avg. 43%), very dark brown to black

in upper soil horizons, and strong clay illuviation into subsurface soil horizons (avg. 29%). A thin (avg. 3 cm thick) litter layer of partially decomposed quaking aspen leaves typically occurs at the surface. A typical soil features an A-Bt horizonation. Diagnostic soil horizons include a thick mollic epipedon (avg. 43 cm thick) and a thick argillic horizon (avg. 53 cm thick). One soil featured a calcic horizon (16+ cm thick) underlying an argillic horizon. When this ET occurs on floodplains, the soils may feature a buried A-horizon. In riparian zones and wetlands, redoximorphic features commonly occur deep in the soil profile. Particle size class included clayey-skeletal [1], fine-loamy [4], and loamy-skeletal [3]. The soils were classified as clayey Mollisols and organic-rich Alfisols, including Typic Argiudolls [4], Pachic Argiudolls [2], Calcic Argiudolls [1], and Mollic Oxyaquic Hapludalfs [1].

Typical pedon description

Soil Classification: Fine-loamy, mixed, superactive, frigid Typic Argiudolls

Oi—0 to 2 cm: slightly decomposed plant material; clear wavy boundary.

A—2 to 10 cm: black (10YR 2/1) very fine sandy loam, very dark gray (10YR 3/1), dry; 59% sand; 14% clay; weak fine subangular blocky structure, and weak fine granular structure; friable, slightly hard, slightly sticky, nonplastic; many fine roots and common medium roots and common coarse roots and common very fine roots; many fine and common medium and common coarse and common very fine pores; 1% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly acid, pH 6.5; clear wavy boundary.

AB—10 to 36 cm: very dark brown (10YR 2/2) and dark brown (10YR 3/3) sandy clay loam, very dark grayish brown (10YR 3/2) and brown (10YR 5/3), dry; 57% sand; 22% clay; moderate medium subangular blocky structure, and moderate fine granular structure; friable, moderately hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common coarse roots and common very coarse roots and common very fine roots; common fine and common medium and common coarse and common very coarse and common very fine pores; 2% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; neutral, pH 6.9; abrupt smooth boundary.

Bt1—36 to 62 cm: brown (7.5YR 4/3) sandy clay loam, light brown (7.5YR 6/3), dry; 47% sand; 25% clay; moderate medium subangular blocky structure, and moderate very fine subangular blocky structure; firm, hard, moderately sticky, very plastic; common fine roots and common medium roots and common coarse roots and common very fine roots; many fine and common medium and common coarse and common very fine pores; 41% patchy distinct clay films on all faces of peds; 4% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; neutral, pH 7.0; gradual wavy boundary.

Bt2—62 to 83 cm: brown (10YR 4/3) medium gravelly sandy clay loam, pale brown (10YR 6/3), dry; 59% sand; 23% clay; moderate very fine subangular blocky structure, and weak medium subangular blocky structure; friable, moderately hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots and common coarse roots; many fine and common medium and common coarse and common very fine pores; 14% patchy faint clay films on all faces of peds; 18% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; neutral, pH 7.1; Gravel is 4% paragravel and 14% gravel; clear wavy boundary.

Bt3—83 to 102 cm: brown (10YR 5/3) medium gravelly sandy clay loam, light yellowish brown (10YR 6/4), dry; 57% sand; 22% clay; moderate very fine subangular blocky structure, and weak medium subangular blocky structure; friable, moderately hard, moderately sticky, moderately plastic; common very fine and fine roots and common medium roots; many fine and common medium and common coarse and common very fine pores; 2% patchy faint clay films on surfaces along root channels and 2% patchy faint clay films on all faces of peds; 5% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 26% nonflat subrounded indurated 2- to 75-mm unspecified fragments; very slight effervescence; slightly alkaline, pH 7.4.

Ecology

"Topoedaphic climax" is a term first used by Steele and others (1981) and derived from the polyclimax theory of Tansley (1935) that refers to deviation from climatic climax (potential natural vegetation found on deep, loamy soils of gently undulating relief) due to a combination of topography and soils. The quaking aspen/sticky purple geranium, Bullflat Family ET is a topoedaphic climax related to concave topography where soil moisture accumulates and with carbon-rich soils characterized by high base saturation, pH, and nutrients. The increased soil moisture in topographic depressions meets the high evapotranspiration demands of quaking aspen. The carbon rich soils, high in pH and nutrients, develop and are maintained through the continual decomposition of fallen aspen leaves. Quaking aspen leaves have high concentrations of cations, acid buffering qualities, and decompose quickly due to a low carbon to nitrogen ratio (Cryer and Murray 1992; Howard 1996; Légaré and others 2005; Pylypec and Redmann 1984). The clay-rich soils of this ET have high water-holding capacity, which also favors quaking aspen at these sites. Quaking aspen is highly adapted to fire (Howard 1996). Periodic wildfire is a key factor in maintaining vigorous quaking aspen stands in the Rocky Mountains. Fire refreshes older stands by opening up the stands, stimulating root sprouting, and removing decadent and diseased trees.

Succession

Forest succession at sites with climax quaking aspen proceeds following stand replacing burns from an initial short-lived herbaceous stage (Bradley and others 1992). Resprouting from rootstock initiates a seedling stage, which typically occurs rapidly during the first year following fire. A fire of any intensity at this point will reset the successional pathway, and repeated fire can maintain quaking aspen in the seedling stage. In the absence of fire, the stand eventually progresses through an immature sucker stage to an even-aged mature aspen stage. In the absence of fire, the even-aged mature aspen stage will eventually give way to a mature stand where openings in the canopy created by individual aspen mortality are filled by regenerating suckers. Low intensity fire at the immature or mature stage will open the stand, lead to a second wave of resprouting, and result in a two-storied aspen stand. Moderate to severe fires at the immature and mature stage will reset the successional pathway. An all-aged climax aspen stand will result from a substantial fire-free period. Low intensity burns are less likely at the climax stage due to high fuel loads that have accumulated throughout the life of the stands. Moderate to high intensity burns will reset the successional pathway.

Management considerations

Forest managers must consider a number of factors when managing the POTR5/GEVI2, Bullflat Family ET, including stand age, reproductive status, and grazing intensity. Young aspen stands (<100 years) that have vigorous regeneration and healthy adult trees require no management activity to maintain. In the absence of disturbance, older (>100 years) aspen stands will begin to deteriorate as they approach climax, resulting in reduced leaf fall (Cryer and Murray 1992). The carbon-rich mollic epipedon begins to lose organic matter and thickness with reduced leaf fall, resulting in increased water percolation, heightened rates of nutrient and organic matter leaching, and production of an eluvial (E-) horizon. Continued leaching results in a thickening of the eluvial horizon and acidification of the soils due to a reduction in base saturation. The deterioration of the stand parallels the deterioration of the soils as quaking aspen regeneration decreases through time. Clear-cutting older, deteriorating aspen stands in order to enhance root sprouting is not recommended as the lower soil nutrients and pH can result in poor post-harvest aspen regeneration. Prescription burning of older, deteriorating aspen stands increases soil pH, adds organic carbon, and contributes nutrients to the soil. Burning also stimulates dense regeneration of root suckers, which contribute to leaf fall and begin the development of carbon rich, high base saturation soils anew. Prescribed burns should be designed to create multi-aged mosaics of the POTR5/GEVI2, Bullflat Family ET across the landscape.

The second factor managers must consider is the interaction between grazing/browsing intensity and reproductive status. Quaking aspen stands that are grazed/browsed and feature regeneration adequate enough that openings in the canopy created by individual aspen mortality are filled by regenerating suckers, require no special management action. Grazed/browsed aspen stands that have little to no regeneration should be protected with exclosures until reproduction reaches pre-grazing levels (Mueggler 1988). Managers should consider a prescribed burn just before constructing exclosures in order to enhance resprouting and refresh the stands. Heavy grazed/browed aspen stands often need to be protected until seedlings grow beyond the reach of grazing/browsing animals (approximately 3 to 5 m in height). This ET is not suited for timber harvest or road construction due to the moist/wet, clay-rich soils that are prone to compaction by heavy equipment.

Similar ecological types

Ecological Type 1

Type: NONE

Table 86—Summary of environmental variables for the POTR5/GEVI2, Bullflat Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,404	2,276	2,490
Slope (%)	14	5	30
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	545	506	576
Degree days	18,820	17,910	20,220
Frost-free days	20.9	20.4	21.4
Site water balance (mm/year)	-292	-354	-210
Average annual temperature (°C)	2.8	2.4	3.3
Total annual potential evapotranspiration (mm)	650	582	720
Summer radiation (KJ)	19,510	17,990	20,380
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	43	4	81
Clay (% in particle size control section)	29	20	39
pH (in particle size control section)	6.5	5.3	7.6
Available water capacity (mm/m)	101	42	162
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	2	0	10
Exposed bedrock	0	0	0
Gravel	1	0	3
Cobble	1	0	3
Stones	1	0	3
Boulders	1	0	5
Litter	37	2	70
Wood	10	3	18
Moss and lichen	1	0	3
Basal vegetation	39	15	60
Water	0	0	0

Table 87—Constancy/cover table for common plant species occurring in the POTR5/GEVI2, Bullflat Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
POTR5	*Populus tremuloides*	quaking aspen	100	34	20	55
Saplings:						
POTR5	*Populus tremuloides*	quaking aspen	88	8	5	10
Seedlings:						
PIFL2	*Pinus flexilis*	limber pine	50	2	1	5
POTR5	*Populus tremuloides*	quaking aspen	88	8	3	15
Shrubs:						
JUCOD	*Juniperus communis* var. *depressa*	common juniper	75	2	1	3
MARE11	*Mahonia repens*	Oregon grape	75	2	1	5
PRVIM	*Prunus virginiana* var. *melanocarpa*	black chokecherry	62	2	1	3
ROWO	*Rosa woodsii*	woods rose	100	2	1	3
SHCA	*Shepherdia canadensis*	russet buffaloberry	75	10	3	20
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	88	2	1	3
AGGL	*Agoseris glauca*	pale agoseris	50	1	1	1
AQCO	*Aquilegia coerulea*	Colorado blue columbine	62	1	1	3
ARCO9	*Arnica cordifolia*	heartleaf arnica	88	5	1	10
ASAUG	*Astragalus australis* var. *glabriusculus*	Indian milkvetch	50	4	1	10
CALI4	*Castilleja linariifolia*	narrow-leaved paintbrush	50	2	1	3
CHAN9	*Chamerion angustifolium*	fireweed	50	1	1	1
FRVI	*Fragaria virginiana*	Virginia strawberry	88	1	1	3
GABO2	*Galium boreale*	northern bedstraw	100	5	1	10
GEVI2	*Geranium viscosissimum*	sticky purple geranium	75	2	1	3
HEQU2	*Helianthella quinquenervis*	nodding helianthella	75	5	1	15
OSDE	*Osmorhiza depauperata*	blunt-fruited sweet-cicely	50	5	3	10
POGR9	*Potentilla gracilis*	slender cinquefoil	62	1	1	3
TAOF	*Taraxacum officinale*	common dandelion	75	2	1	3
THOC	*Thalictrum occidentale*	western meadowrue	50	2	1	5
VIOLA	*Viola*	violet	50	1	1	1
Grasses:						
POPR	*Poa pratensis*	Kentucky bluegrass	75	6	1	20
TRSP2	*Trisetum spicatum*	spike trisetum	50	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 88—Stand characteristics for the POTR5/GEVI2, Bullflat Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/ha---		-------Centimeters-------			
PICOL	4.6	—	26.9	22.6–31.0	87	—
POTR5	34.4	20.7–50.5	20.3	8.4–32.8	1,376	548–3,451
PSMEG	4.6	—	46.7	43.9–49.3	27	—

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
PICOL	31.0	17	100
POTR5	20.1	16	—
PSMEG	49.3	—	101

Quaking Aspen/Utah Snowberry-Boulder, Ledgefork Family Ecological Type

Populus tremuloides/*Symphoricarpos oreophilus* var. *utahensis*-Boulder, Ledgefork Family Ecological Type

POTR5/SYORU-Boulder, Ledgefork Family ET

N = 4

Distribution

The quaking aspen/Utah snowberry-Boulder, Ledgefork Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs primarily to the south of Louis Lake. This ET is a component of map units 44L, 310A, and 317L.

Environment

Aspect: East [1], east-southeast [1], southeast [1], south-southwest [1].

Landforms and Landscape Position: Mountain slopes. Shoulders, backslopes, and footslopes.

Parent Materials: Granodiorite colluvium.

Bedrock: Granodiorite of the Louis Lake Pluton.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 61.9 to 64.2 cm.

Additional environment data summaries are provided in Table 89.

Potential natural vegetation

The potential natural vegetation of this ecological type is the quaking aspen/Utah snowberry plant association (Reed 1971). The POTR5/SYORU-Boulder, Ledgefork Family ET is unique in that it occurs on steep, bouldery slopes. Quaking aspen is always present in the overstory and sometimes shares dominance with lodgepole pine. Quaking aspen forms an open-canopy forest and is always present and vigorously reproducing in the understory. Conifer seedlings often occur in the understory, including lodgepole pine and limber pine; however, regeneration is generally limited. Utah snowberry and Oregon grape are always present at low abundance. Common juniper may occur at high abundance when it is present. Other common shrubs include woods rose, snowbrush ceanothus, western serviceberry, and grayleaf red raspberry. The herbaceous layer is very species rich; however, only a few species are very abundant. Heartleaf arnica is always present. Fireweed, squirreltail, muttongrass, and Ross' sedge are nearly always present. Spreading dogbane and three-nerve goldenrod are two species unique to this ecological type. Summaries of species constancy/cover and stand characteristics are provided in Tables 90 and 91, respectively.

Soils

Soils in the POTR5/SYORU, Ledgefork Family ET are moderately deep and deep, sandy, and extremely bouldery with a low degree of soil development, high coarse fragments (avg. 78%) and low clay (avg. 11%). A thin (avg. 5 cm thick) litter layer of partially decomposed quaking aspen leaves occurs at the surface. A typical soil features an A/Bw/C horizonation. The C-horizons tended to be extremely bouldery (60-90%). Diagnostic soil horizons include a thick mollic epipedon (avg. 51 cm thick). Inceptisols and Entisols featured an ochric epipedon (avg. 12 cm thick). Particle size class was loamy-skeletal [2] and sandy-skeletal [2]. The soils were classified as Pachic Haplocryolls [1], Typic Haplocryolls [1], Typic Eutrocryepts [1], and Typic Cryorthents [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Typic Haplocryolls

Oi—0 to 4 cm: slightly decomposed plant material; 32% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; abrupt wavy boundary.

Oe—4 to 9 cm: moderately decomposed plant material; 35% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; abrupt wavy boundary.

A1—9 to 32 cm: very dark grayish brown (10YR 3/2) very gravelly sandy loam, dark grayish brown (10YR 4/2), dry; 66% sand; 17% clay; weak fine subangular blocky structure, and weak medium granular structure; friable, slightly hard, moderately sticky, nonplastic; common very fine and fine roots and many medium roots and common coarse roots; common very fine and fine and many medium and common coarse pores; 3% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 17% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 38% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.5; gradual wavy boundary.

A2—32 to 58 cm: dark brown (10YR 3/3) very gravelly loamy sand, pale brown (10YR 6/3), dry; 88% sand; 7% clay; weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very coarse roots and common very fine roots; common fine and common medium and common very coarse and common very fine pores; 5% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 35% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; strongly acid, pH 5.5; clear smooth boundary.

C—58 to 106 cm: brown (10YR 4/3) bouldery sandy clay loam, pale brown (10YR 6/3), dry; 89% sand; 6% clay; single grain; loose, slightly sticky, nonplastic; common very fine and fine roots and common medium roots; common very fine and fine and common medium pores; 3% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 9% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 27% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 52% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; moderately acid, pH 5.6.

Ecology

The extensive root system, root sprouting ability, and overall hardy nature of quaking aspen make it a successful pioneer species on harsh sites. On extremely rocky sites, quaking aspen is found stunted and gnarled growing between boulders. The extremely bouldery soil surface precludes conifers from reaching dominance, resulting in a stable aspen forest. The POTR5/SYORU-Boulder, Ledgefork Family ET represents upper elevation, relatively dry, quaking aspen forests on granitic parent materials. At these higher elevations, contiguous quaking aspen forests are limited to warmer, southerly slopes. The boulder-covered soil surface acts as a sink for heat from the sun. The heat collected in the boulders is re-radiated at night, resulting in a warmer microclimate and extending this ET to higher elevations.

Succession

Forest succession begins following a stand replacing burn from an initial short-lived herbaceous/shrub stage (A) (Bradley and others 1992). Resprouting of quaking aspen from rootstock and sprouting of scattered lodgepole pine initiates a mixed quaking aspen-lodgepole pine seedling stage (B), which typically occurs rapidly during the first year following fire. A fire of any intensity at this point will reset the successional pathway, and repeated fire can maintain quaking aspen in the seedling stage. In the absence of fire, the stand eventually progresses through an immature sucker stand with scattered lodgepole pine (C) to an open, even-aged, mature aspen stand with scattered, pole-sized lodgepole pine (D). In the absence of fire, the even-aged mature aspen stage will eventually give way to an open-canopied mature stand with scattered mature lodgepole pine (E) where openings in the canopy created by individual aspen mortality are filled by regenerating suckers. Lodgepole pine regeneration is generally limited as the understory begins to get shaded out beginning in stage (D). Low intensity fire at the immature or mature stage will open the stand, lead to a second wave of resprouting, and result in a two-storied aspen stand. Moderate to severe fires at the immature and mature stage will reset the successional pathway. An all-aged climax aspen stand will result from a substantial fire-free period. Low intensity burns are less likely at the climax stage due to high fuel loads that have accumulated throughout the life of the stands. Moderate to high intensity burns will reset the successional pathway.

Management considerations

This ET is not suited for timber harvest or cattle grazing due to the extremely bouldery soil surface. Prescribed burns can be used to refresh older stands by stimulating root sprouting, and removing decadent and diseased trees. This ET has high aesthetic and wildlife value. Elk and deer may browse aspen in these stands; however, use is generally low to moderate due to the bouldery nature of the soil surface. This ET provides important habitat for cavity nesting birds, grouse, owls, and small mammals. This ET contributes to the landscape mosaic of conifer, sagebrush, and grassland by adding patches of deciduous forest. In the fall of the year, the brilliant red, yellow, and orange quaking aspen foliage provides a perfect backdrop for recreationists enjoying National Forest lands.

Similar ecological types

Ecological Type 1

Type: NONE

Table 89—Summary of environmental variables for the POTR5/SYORU-Boulder, Ledgefork Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,664	2,651	2,688
Slope (%)	49	28	57
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	627	619	642
Degree days	15,850	15,460	16,060
Frost-free days	19.4	19.2	19.5
Site water balance (mm/year)	-347	-317	-292
Average annual temperature (°C)	1.5	1.4	1.6
Total annual potential evapotranspiration (mm)	614	579	651
Summer radiation (KJ)	20,370	19,960	20,600
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	78	70	82
Clay (% in particle size control section)	11	7	15
pH (in particle size control section)	5.3	4.8	6.0
Available water capacity (mm/m)	36	27	49
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	0	5
Exposed bedrock	5	0	10
Gravel	3	0	5
Cobble	4	3	5
Stones	5	5	5
Boulders	23	10	35
Litter	25	15	40
Wood	11	5	15
Moss and lichen	1	0	2
Basal vegetation	20	10	20
Water	0	0	0

Table 90—Constancy/cover table for common plant species occurring in the POTR5/SYORU-Boulder, Ledgefork Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Dominant overstory trees:						
POTR5	*Populus tremuloides*	quaking aspen	75	18	15	20
Subominant overstory trees:						
POTR5	*Populus tremuloides*	quaking aspen	50	6	3	10
Saplings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	2	1	3
POTR5	*Populus tremuloides*	quaking aspen	100	19	5	25
Seedlings:						
PICOL	*Pinus contorta* var. *latifolia*	lodgepole pine	75	3	3	3
POTR5	*Populus tremuloides*	quaking aspen	100	7	3	15
Shrubs:						
CEVE	*Ceanothus velutinus*	shinyleaf ceanothus	50	3	3	3
JUCOD	*Juniperus communis* var. *depressa*	common juniper	75	5	3	10
MARE11	*Mahonia repens*	Oregon grape	100	3	1	5
ROWO	*Rosa woodsii*	woods rose	75	2	1	5
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	100	3	1	5
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	50	1	1	1
ANRO2	*Antennaria rosea*	rosy pussy-toes	50	2	1	3
ANTEN	*Antennaria*	pussy-toes	50	1	1	1
APAN2	*Apocynum androsaemifolium*	spreading dogbane	50	2	1	3
ARCO9	*Arnica cordifolia*	heartleaf arnica	100	5	1	10
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	50	1	1	1
CALI4	*Castilleja linariifolia*	narrow-leaved paintbrush	50	1	1	1
CHAN9	*Chamerion angustifolium*	fireweed	75	2	1	5
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	50	1	1	1
Grasses:						
ELEL5	*Elymus elymoides*	squirreltail	75	2	1	3
LEKI2	*Leucopoa kingii*	spike-fescue	50	1	1	1
PIEX3	*Piptatherum exiguum*	little ricegrass	50	1	1	1
POFE	*Poa fendleriana*	muttongrass	75	6	1	15
POWH2	*Poa wheeleri*	Wheeler's bluegrass	50	2	1	3
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	75	4	3	5

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Table 91—Stand characteristics for the POTR5/SYORU-Boulder, Ledgefork Family ET.

	Basal area		Diameter at breast height (DBH)		Trees per hectare	
Species	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
	---m^2/*ha*---		-------*Centimeters*-------			
PICOL	6.9	2.3–16.1	17.0	8.9–26.2	412	245–625
POTR5	17.7	11.5–25.3	14.5	7.6–22.4	1,368	931–2,060

	Site tree averages		
Species	**DBH**	**Height**	**Age**
	Centimeters	*Meters*	*Years*
	14.0	—	35
	14.2	—	—

Miscellaneous Quaking Aspen Types

Quaking Aspen/Red-Osier Dogwood-sitka Alder Habitat Type

Populus tremuloides/*Cornus sericea*-*Alnus viridis* var. *sinuata* Habitat Type

POTR5/COSE16-ALVIS HT

N = 2

The quaking aspen/red-osier dogwood-Sitka alder habitat type is the vegetation phase of two Ecological Types: (1) Mantador Family ET, and (2) Caryville Family ET. The Mantador Family ET occurs in the Granitic Subalpine Zone ecoregion of Chapman and others (2004) and is a component of map unit 351L. The Manador Family ET occurred in a seep on a moderately steep (8%) slope along the upper section of Sinks Canyon in the Middle Fork Popo Agie drainage. This ET likely occurs in map unit 302 along steep (typically <10%), bouldery stream reaches; however, this ET was never sampled in this map unit. Soils were low in coarse fragments (34%), sandy, and featured abundant redoximorphic features. Depth to water table was 60 cm. Soils were moderately deep, sandy-skeletal Aquic Pachic Hapludolls.

The Caryville Family ET occurred within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004) and is a component of map unit 402L. This ET likely occurs in map unit 302 along steep (typically ≥10%), bouldery stream reaches; however, this ET was never sampled in this map unit. This ET occurred on the banks of a steep (>10%), narrow stream reach in mixed sandstone and granite alluvium over Flathead Sandstone residuum. Soils were low in coarse fragments (14%), sandy, and minimally developed. Soils were composed of increasingly younger alluvial deposits layered atop one another. A buried A-horizon (Ab) occurred between 43 and 63 cm. Soils were deep, loamy-skeletal, Mollic Udifluvents.

Potential natural vegetation of both the Matador Family ET and Caryville Family ET is the quaking aspen/red-osier dogwood-Sitka alder habitat type. This habitat type has not previously been described. Quaking aspen dominates all canopy layers. Lodgepole pine may co-occur in the overstory but generally has limited regeneration in the understory. Subalpine fir seedlings may occur on drier sites on the upper section of streambanks. Sitka alder and/or red-osier dogwood are always present and growing in or near the stream channel. Other common shrubs include woods rose, black chokecherry, Rocky Mountain maple, twinberry honeysuckle, Canadian gooseberry, and northern black and prickly currants. Grouse whortleberry and kinnikinnick may be found higher on streambanks in drier soils. The herbaceous layer is especially species rich. Important indicator species include baneberry, white geranium, clasp-leaved twisted-stalk, fewflower meadow-rue, common cowparsnip, starry false lily of the valley, variegated scouring rush, and blue wildrye. James' monkeyflower and American mannagrass may occur in wetter, lower gradient microsites. Sidebells and pink wintergreen, heartleaf arnica, fireweed, Ross' sedge, and Columbia needlegrass may occur in drier soils high on the streambanks.

The POTR5/COSE16-ALVIS HT is important habitat for moose, which browse on young quaking aspen and red-osier dogwood stems. Reptiles and amphibians also take refuge in this habitat type. The dense stems and strong roots of red-osier dogwood and Sitka alder provide streambank stability. The roots of Sitka alder have a symbiotic relationship with nitrogen-fixing bacteria, which can convert atmospheric nitrogen (N2) into biologically useful forms of nitrogen (NH3), thus enriching the soil.

Upland Shrubland Series

Wyoming Three-tip Sagebrush Series

Principal Species Descriptions

Wyoming Three-tip Sagebrush

Artemisia tripartita Rudb. var. *rupicola* (Beetle) Dorn

Three-tip sagebrush (*Artemisia tripartita*) includes two varieties that are morphologically and geographically distinct (McArthur and Taylor 2004). Variety tripartita, also called tall three-tip sagebrush, occurs as far north as central British Columbia, throughout the Columbia River Basin of northern Nevada, Oregon, and Washington, and into the Snake River Basin of western Wyoming, central and southern Idaho, and eastern Oregon, and is a free-branching shrub ranging from 20 to 150 cm in height (Shultz 2006). Variety *rupicola*, also called Wyoming three-tip sagebrush, occurs only in central Wyoming east of the Continental Divide and is a dwarf-shrub, with decumbent branches, ranging from 5 to 15 cm in height. Across the eastern slope of the WRR variety *rupicola* is the representative variety of three-tip sagebrush; therefore, the remainder of this description will focus primarily on this variety.

Wyoming three-tip sagebrush commonly occurs on dry, windy, south- and west-facing, shoulders, summits, and steep upper backslopes. Soils where Wyoming three-tip sagebrush grows are typically well-drained, moderately deep (50–100 cm) to deep (>100 cm) and sometimes shallow (<50 cm), gravelly (15–60%) in the upper horizons, and medium- to coarse-textured, including loam, fine sandy loam, sandy loam, coarse sandy loam, and loamy sand. Wyoming three-tip sagebrush occurs across a variety of substrate types, including limestone, dolomite, shale, siltstone, granodiorite, metagabbro, and metadiorite. On the east slope of the WRR in Wyoming, Wyoming three-tip sagebrush occurs between roughly 1,800 and 3,200 m (Massatti 2007).

Wyoming three-tip sagebrush reproduces by seed and vegetatively by sprouting from the rootcrown or layering (Tirmenstein 1999a). However, sprouting ability varies by geographic location, suggesting ecotypic variation. Young flowerheads begin developing in July and flowering takes place between late August and early October. The small, light seeds ripen in October and are wind dispersed, allowing for rapid re-establishment in disturbed areas.

Wyoming three-tip sagebrush is moderately to severely damaged by fire (Tirmenstein 1999a). Root sprouting usually occurs following low to moderate severity fires, which kills the above ground portion of plants. However, resprouting ability is highly variable depending on geographic location and soil moisture status. Sprouting success is highest when Wyoming three-tip sagebrush burns in the late winter or early spring while soils are still moist. Severe fires lead to mortality of both above and below ground portions of the plants. Re-establishment following severe fires is exclusively from seed. Fire regimes in Wyoming three-tip sagebrush communities often match those of co-occurring species, including Idaho fescue (3–40 years) or bluebunch wheatgrass (17–62 years) and adjacent mountain big sagebrush communities (15–40 years) (Johnson 2000; Zlatnik 1999b; Zouhar 2000).

Wyoming three-tip sagebrush is one of the least palatable species for both domestic and wild ungulates within the genus *Artemisia* and is actually considered slightly toxic to domestic livestock (Tirmenstein 1999a). Wyoming three-tip sagebrush is of low cover value to large mammals and upland game birds due to its low stature. However, small mammals and ground nesting songbirds may take refuge in Wyoming three-tip sagebrush communities. Wyoming three-tip sagebrush also adds structural and biological diversity to the landscapes and is an integral part in reducing the effects of wind on soil erosion. Wyoming three-tip sagebrush is recommended for use in rehabilitation of disturbed sites. Trampling of Wyoming three-tip sagebrush by domestic livestock can negatively affect the abundance of this species in grazing allotments.

Wyoming Three-tip Sagebrush/Idaho Fescue, Ledgefork Family Ecological Type

Artemisia tripartita var. *rupicola*/ *Festuca idahoensis*, Ledgefork Family Ecological Type

ARTRR4/FEID, Ledgefork Family ET

N = 3

Distribution

The Wyoming three-tip sagebrush/Idaho fescue, Ledgefork Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs to the south and east of Louis Lake in a network of diabasic gabbro dikes that have intruded into the Louis Lake Pluton (Bayley and others 1973). This ET is a component of map unit 309L.

Environment

Aspect: North-northwest [1], west [1], west-northwest [1].

Landforms and Landscape Position: Diabasic gabbro dikes. Shoulders and upper backslopes.

Parent Materials: Diabasic gabbro colluvium over Louis Lake Granodiorite residuum. Louis Lake Granodiorite residuum.

Bedrock: Louis Lake Granodiorite, diabasic gabbro.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 67 to 68 cm.

Additional environment data summaries are provided in Table 92.

Potential natural vegetation

The potential natural vegetation of this ecological type includes Wyoming three-tip sagebrush/Idaho fescue habitat type. At first glance, these sites look more like grasslands than a sagebrush community. The low growing (<10 cm) Wyoming three-tip sagebrush is hidden among the grasses and appears as if it had been strewn about at random. The herbaceous layer is scant and relatively unproductive when compared to sagebrush communities growing on calcareous parent materials. Idaho fescue, Sandberg bluegrass, and bluebunch wheatgrass dominate the herbaceous layer, the latter indicative of the drier site conditions at these exposed upper backslopes, shoulders, and summits. Other common herbaceous species include timber milkvetch, ballhead sandwort, cutleaf daisy, cushion buckwheat, bitterroot, Hood's and many-flowered phlox, and lance-leaved stonecrop. Mosses and lichens form a dense layer at the soil surface. The layer of mosses and lichens aids in protecting the soil surface from erosion by wind and water. Bare ground and gravels are also prevalent at the soil surface, forming an extensive erosion pavement. Table 93 provides a summary of species constancy and cover for this ecological type.

Soils

The soils at these sites are shallow to moderately deep to grus (Cr-horizon), a type of partially decomposed bedrock that has weathered to gravel-sized rock fragments. The grus is dense, prohibitive to root penetration, and extremely low in clay. Soils occurring on or near dikes, and derived from diabasic gabbro colluvium over granodiorite residuum have an average pH higher than ~6.0, reflecting the greater concentration of cations (Ca^{2+}, Mg^{2+}) in the diabasic gabbro.

Soils in the ARTRR4/FEID, Ledgefork Family ET are mostly shallow to moderately deep and gravelly with a low to moderate degree of soil development, moderate to high coarse fragments (44–72%, avg. 54%), and low to moderate amounts of clay (5–23%, avg. 16%). A typical soil features an A/Bw-Bt/C-Cr horizonation. Distinguishing soil horizons include a mollic epipedon (avg. 25 cm thick), and shallow to moderately deep paralithic or lithic contact (avg. 68 cm depth). Typic Argicryolls display an argillic horizon

(avg. 18 cm) between the mollic epipedon and paralithic contact (avg. 79 cm depth). One soil was deep, with a 26-cm thick A-horizon over a thin Bw-horizon (15 cm thick), over a thick (64 cm thick), sandy (>90%), extremely gravelly C-horizon. The soils classified as loamy-skeletal Typic Argicryolls [2], and sandy-skeletal Typic Haplocryolls [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Typic Haplocryolls

A1—0 to 8 cm: very dark brown (10YR 2/2) very gravelly coarse sandy loam, dark grayish brown (10YR 4/2), dry; 70% sand; 9% clay; moderate coarse subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 3% 76- to 250-mm unspecified fragments and 10% 251- to 600-mm unspecified fragments and 28% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; neutral, pH 6.6; clear wavy boundary.

A2—8 to 27 cm: dark brown (10YR 3/3) very gravelly coarse sandy loam, brown (10YR 4/3), dry; 72% sand; 8% clay; moderate coarse subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 4% 76- to 250-mm unspecified fragments and 15% 251- to 600-mm unspecified fragments and 34% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.5; clear smooth boundary.

Bw—27 to 41 cm: brown (10YR 4/3) very gravelly loamy coarse sand, brown (10YR 5/3), dry; 82% sand; 5% clay; weak medium subangular blocky structure, and moderate fine granular structure; friable, slightly hard, nonsticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 9% 76- to 250-mm unspecified fragments and 42% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.5; clear wavy boundary.

CB—41 to 72 cm: variegated; extremely gravelly coarse sand, pale brown (10YR 6/3), dry; 88% sand; 4% clay; weak fine subangular blocky structure; very friable, slightly hard, nonsticky, nonplastic; common medium roots and common very fine roots; common medium and common very fine pores; 69% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.3; gradual broken boundary.

2C—72 to 97 cm: variegated; extremely gravelly coarse sand; 90% sand; 3% clay; single grain; loose, nonsticky, nonplastic; common very fine roots; common very fine pores; 81% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.2; abrupt smooth boundary.

2Cr—97 to 112 cm: variegated; 94% sand; 4% clay; single grain; loose, nonsticky, nonplastic; common very fine roots; common very fine pores; 1% 76- to 250-mm unspecified fragments and 90% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.2.

Ecology

The ARTRR4/FEID, Ledgefork Family ET, with the exception of the dominant sagebrush species, is similar vegetatively to the ARTRV2/FEID, Ledgefork Family ET. However the two Ecological Types inhabit distinctly different slope positions depending on the dominant sagebrush species. Mountain big sagebrush is most successful on deep, well-drained, medium- to coarse-textured soils and is most often found on loams or sandy-loams with high amounts of coarse fragments (35-70%) (Welch 2005). Unlike Wyoming three-tip sagebrush, which is adapted to cold, windswept, xeric conditions typical of upper backslope, shoulder, and summit positions, mountain big sagebrush in Wyoming has been shown to prefer lower, less exposed slope positions (Burke and others 1989). Wind deflation is an important geomorphic process at these sites, as is evidenced by extensive erosion pavement of gravel-sized rock fragments.

Management considerations

The ARTRR4/FEID, Ledgefork Family ET provides important foraging grounds for domestic and wild ungulates.

Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer. These summit and shoulder positions are typically blown free of snow during the winter months, resulting in very little protection from extremely cold temperatures, frigid wind chill effects, and physical abrasion from snow and ice particles. The unproductive nature of these communities results in a minimal accumulation of fuels. Fires in the ARTRR4/FEID, Ledgefork Family ET, especially later in the season, are expected to be rapid and of low to moderate intensity, resulting in minimal damage to sagebrush or Idaho fescue. Response of Idaho fescue and Wyoming three-tip sagebrush is generally positive following low to moderate severity burns (Tirmenstein 1999a; Zouhar 2000).

Similar ecological types

Ecological Type 1

Type: Mountain big sagebrush/Idaho fescue, Ledgefork Family ET

Floristic differences: The two types differ floristically in the dominant sagebrush, including Wyoming three-tip sagebrush in the ARTRR4/FEID, Ledgefork Family ET and mountain big sagebrush in the ARTRV2/FEID, Ledgefork Family ET.

Environmental differences: The types differ environmentally in that the ARTRR4/FEID, Ledgefork Family ET occurs on shoulders and upper backslopes, while the ARTRV2/FEID, Ledgefork Family ET occurs on lower backslopes and footslopes and areas of gentle topography.

Table 92—Summary of environmental variables for the ARTRR4/FEID, Ledgefork Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,776	2,768	2,792
Slope (%)	15	10	18
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	674	668	680
Degree days	14,570	14,480	14,670
Frost-free days	18.8	18.7	18.9
Site water balance (mm/year)	-268	-280	-256
Average annual temperature (°C)	1.1	1.0	1.2
Total annual potential evapotranspiration (mm)	555	546	564
Summer radiation (KJ)	20,100	19,780	20,410
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	54	44	72
Clay (% in particle size control section)	16	5	23
pH (in particle size control section)	6.0	5.9	6.1
Available water capacity (mm/m)	33	23	42
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	1	5
Exposed bedrock	1	0	2
Gravel	23	15	30
Cobble	2	1	3
Stones	2	1	3
Boulders	1	0	2
Litter	13	10	15
Wood	0	0	0
Moss and lichen	20	15	25
Basal vegetation	28	15	40
Water	0	0	0

Table 93—Constancy/cover table for common plant species occurring in the ARTRR4/FEID, Ledgefork Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARTRR4	*Artemisia tripartita*	Wyoming three-tip sagebrush	100	8	3	10
Forbs:						
ASMI9	*Astragalus miser*	timber milkvetch	67	1	1	1
ERCA2	*Erigeron caespitosus*	tufted fleabane	67	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	67	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	67	1	1	1
EROV	*Eriogonum ovalifolium*	cushion buckwheat	67	1	1	1
LERE7	*Lewisia rediviva*	bitterroot	67	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	67	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	67	2	1	3
PHMU3	*Phlox multiflora*	many-flowered phlox	67	4	3	5
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	100	2	1	3
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	67	4	3	5
FEID	*Festuca idahoensis*	Idaho fescue	100	9	3	20
POSE	*Poa secunda*	Sandberg bluegrass	67	12	10	15

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Wyoming Three-tip Sagebrush/ Bluebunch Wheatgrass, Bigsheep Family Ecological Type

Artemisia tripartita var. *rupicola*/ *Elymus spicatus*, Bigsheep Family Ecological Type

ARTRR4/ELSP3, Bigsheep Family ET

N = 6

Distribution

The Wyoming three-tip sagebrush/bluebunch wheatgrass, Bigsheep Family Ecological Type occurs in the northern and southern study areas within the dry, mid-elevation, sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 15L.

Environment

Aspect: South-southeast [1], south-southwest [3], southwest [1], west-southwest [1].

Landforms and Landscape Position: Upper backslopes and shoulders.

Parent Materials: Bighorn Dolomite and/or Gallatin Limestone colluvium over residuum.

Bedrock: Cambrian Gros Ventre Shale, Cambrian Gallatin Limestone.

This ecological type occurs on upper backslopes and shoulders near the contact between the Gros Ventre and Gallatin Formations. The type of bedrock at a particular site will vary depending on the slope position relative to the particular geologic stratigraphy at each site.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 56 to 67 cm.

Additional environment data summaries are provided in Table 94.

Potential natural vegetation

The potential natural vegetation of this ecological type is the Wyoming three-tip sagebrush/bluebunch wheatgrass habitat type. Upon a cursory look, these sites may appear to be grasslands, although further scrutiny reveals the low-growing Wyoming three-tip sagebrush and fringed sagewort growing beneath a dense layer of bluebunch wheatgrass and Sandberg bluegrass. Yellow rabbitbrush occurs regularly and at low abundance in this habitat type.

Forbs are generally sparse at these exposed and windy sites. Turpentine wavewing, white locoweed, woolly groundsel, and cushion plants, including Hood's and many-flowered phlox, and stemless and narrowleaf mock goldenweeds are the most common and abundant forbs. Fremont's bladderpod, an endemic species of mustard that occurs only in Fremont County, Wyoming, was found growing in this ecological type. Table 95 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the ARTRR4/ELSP3, Bigsheep Family ET are deep and calcareous with a low to moderate degree of soil development, moderate to high coarse fragments (39–73%, avg. 53%), and low to moderate clay (12–23%, avg. 17%). A typical soil featured an A/Bk horizonation. Diagnostic soil horizons include a gravelly mollic epipedon (avg. 34 cm thick), and a thick (avg. 70 cm thick) calcic horizon. Particle size class was loamy-skeletal. Soils were Typic Calciustolls [5] and Pachic Calciustolls [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Typic Calciustolls

A1—0 to 11 cm: brown (10YR 4/3) fine gravelly fine sandy loam, very dark brown (10YR 2/2), moist; 54% sand; 15% clay; moderate fine subangular blocky structure, and moderate medium granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 1% fine faint carbonate nodules in matrix; 23% 2- to 75-mm unspecified fragments; slight effervescence, by HCl, 1 normal; moderately alkaline, pH 8.0; abrupt wavy boundary.

A2—11 to 21 cm: dark yellowish brown (10YR 4/4) very gravelly fine sandy loam, very dark grayish brown (10YR 3/2), moist; 58% sand; 14% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 10% fine faint carbonate nodules in matrix and 1% medium distinct carbonate nodules in matrix; 15% flat 150- to 380-mm unspecified fragments and 37% 2- to 75-mm unspecified fragments; slight effervescence, by HCl, 1 normal; moderately alkaline, pH 8.1; clear wavy boundary.

Bk1—21 to 55 cm: pale yellow (2.5Y 7/4) very gravelly fine sandy loam, light yellowish brown (2.5Y 6/3), moist; 51% sand; 17% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; prominent carbonate coats on rock fragments; 10% fine distinct carbonate nodules in matrix; 5% flat 150- to 380-mm unspecified fragments and 48% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; strongly alkaline, pH 8.6; gradual smooth boundary.

2Bk2—55 to 101 cm: pale yellow (2.5Y 7/3) extremely gravelly fine sandy loam, light yellowish brown (2.5Y 6/4), moist; 62% sand; 16% clay; moderate fine subangular blocky structure, and moderate medium granular structure; friable, moderately hard, slightly sticky, slightly plastic; common fine roots; common fine pores; prominent carbonate coats on rock fragments; 10% distinct carbonate masses on surfaces along root channels and 10% faint carbonate nodules in matrix; 12% flat 150- to 380-mm unspecified fragments and 51% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; strongly alkaline, pH 8.7.

Ecology

The reduced stature of Wyoming three-tip sagebrush is an adaptation to the cold, droughty conditions brought about by strong winds and intense solar radiation experienced at these steep, exposed upper backslope and shoulder positions. Many of the slopes where this ET occurred were west facing. The effect of solar radiation is more intense on west-facing than east-facing slopes because the air temperature in the afternoon, when the sun is shining directly on a west-facing slope, is higher than in the morning, when the sun is shining directly on an east-facing slope. West-facing upper backslopes and shoulders in the WRR are highly exposed to the prevailing westerly winds, further increasing drought conditions at these sites. During the winter months, these windswept upper backslopes and shoulders are continually blown free of snow, resulting in very little protection from extremely cold temperatures, frigid wind chill effects, and physical abrasion from snow and ice particles. Wind deflation is at a maximum at these sites, as evidenced by extensive erosion pavement.

Management considerations

The ARTRR4/ELSP3, Bigsheep Family ET provides important foraging grounds for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer.

The unproductive nature of these communities results in a minimal accumulation of fuels. Fires in the ARTRR4/ELSP3, Bigsheep Family ET, especially later in the season, are expected to be rapid and of low to moderate intensity, resulting in minimal damage to Wyoming three-tip sagebrush. Response of Wyoming three-tip sagebrush is generally positive following low to moderate severity burns (Tirmenstein 1999a). However, fires that start in mountain big sagebrush communities located downslope from this ET may result in severe fires that move upslope into the ARTRR4/ELSP3, Bigsheep Family ET. In the case of severe fire, Wyoming three-tip sagebrush can be completely extirpated from a site, returning only very slowly from seed blown in from nearby plants.

Fire generally favors bluebunch wheatgrass and stimulates flowering, seed, and tiller production (Zlatnik 1999b). Seasonality of fires strongly affects mortality. Bluebunch wheatgrass receives the least damage when burned while dormant in fall, winter, or early spring and the most damage when burned while actively growing in the late spring and summer. Soil moisture status prior to and following fires also affects mortality and recovery time. Recovery following fires is generally rapid (one-five years); however, a lack of adequate soil moisture following a burn can slow recovery and increase mortality. Low soil moisture prior to burning increases fire severity.

Bluebunch wheatgrass is moderately tolerant of grazing and is considered a grazing decreaser since heavy grazing can result in lower root and stem carbohydrate reserves, a condition leading to decreased vigor or mortality. Bluebunch wheatgrass is most sensitive to grazing during its active growth period in spring and early summer. Trampling of Wyoming three-tip sagebrush by domestic livestock can negatively affect the abundance of this species in grazing allotments.

Similar ecological types

Ecological Type 1

Type: NONE

Table 94—Summary of environmental variables for the ARTRR4/ELSP3, Bigsheep Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,628	2,429	2,753
Slope (%)	30	13	39
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	627	559	670
Degree days	16,300	15,080	18,570
Frost-free days	19.6	19.0	20.7
Site water balance (mm/year)	-325	-422	-253
Average annual temperature (°C)	1.8	1.2	2.7
Total annual potential evapotranspiration (mm)	662	612	741
Summer radiation (KJ)	20,820	20,570	20,960
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	53	39	73
Clay (% in particle size control section)	17	12	23
pH (in particle size control section)	8.1	7.8	8.5
Available water capacity (mm/m)	59	36	94
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	8	2	15
Exposed bedrock	0	0	0
Gravel	35	15	60
Cobble	2	0	5
Stones	1	0	5
Boulders	1	0	2
Litter	8	5	10
Wood	1	0	3
Moss and lichen	1	0	2
Basal vegetation	46	25	70
Water	0	0	0

Table 95—Constancy/cover table for common plant species occurring in the ARTRR4/ELSP3, Bigsheep Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARFR4	*Artemisia frigida*	fringed sagewort	67	5	1	10
ARTRR4	*Artemisia tripartita*	Wyoming three-tip sagebrush	100	20	7	35
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	50	1	1	1
Forbs:						
AGGL	*Agoseris glauca*	pale agoseris	50	2	1	3
ASMI9	*Astragalus miser*	timber milkvetch	67	2	1	3
BAIN	*Balsamorhiza incana*	hoary balsamroot	67	1	1	1
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	67	3	1	5
ERAS2	*Erysimum asperum*	sanddune wallflower	67	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	67	2	1	3
ERRY	*Erigeron rydbergii*	northwestern fleabane	67	1	1	1
LEFR4	*Lesquerella fremontii*	Fremont's bladderpod	50	1	1	1
LILE3	*Linum lewisii*	prairie flax	67	1	1	2
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	67	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	67	1	1	1
OXSE	*Oxytropis sericea*	white locoweed	100	5	1	15
PACA15	*Packera cana*	woolly groundsel	83	1	1	3
PEHU	*Penstemon humilis*	low beardtongue	50	2	1	3
PHHO	*Phlox hoodii*	Hood's phlox	83	3	1	7
PHMU3	*Phlox multiflora*	many-flowered phlox	83	3	1	10
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	50	1	1	1
TAER2	*Taraxacum eriophorum*	wool-bearing dandelion	50	2	1	3
ZIVEG	*Zigadenus venenosus* var. *gramineus*	grassy deathcamas	50	1	1	1
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	19	5	30
LEKI2	*Leucopoa kingii*	spike-fescue	67	3	1	5
POSE	*Poa secunda*	Sandberg bluegrass	100	21	5	40

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Mountain Big Sagebrush Series

Principal Species Descriptions

Mountain Big Sagebrush

Artemisia tridentata Nutt. var. *vaseyana* (Rydb.) Boivin

Big sagebrush (*Artemisia tridentata*) includes four widely recognized varieties or subspecies that are morphologically and ecologically distinct (Dorn 2001). Variety *tridentata*, also called Great Basin big sagebrush, is a tall shrub (1–2 m) common to deep, well-drained soils along valley bottoms, lower montane slopes, and drainages at elevations between 1,300 and 2,200 m in major basins across the western United States and Canada (Shultz 2006). Precipitation in Great Basin big sagebrush communities ranges between 26 and 44 cm. Variety *wyomingensis* is a low to moderately tall shrub (30–50 cm) that occurs in valleys and high plateaus at elevations between 800 and 2,200 m across the western United States and Canada. Precipitation in Wyoming big sagebrush communities ranges between 20 and 32 cm (Welch 2004). Variety *vaseyana*, also called mountain big sagebrush, is a low to moderately tall shrub (60–80 cm) that occurs on mountain slopes between 1,200 and 3,200 m in British Columbia and all western states except Arizona and New Mexico (Shultz 2006; Svalberg and others 1997; Tweit and Houston 1980). Precipitation in mountain big sagebrush communities ranges between 31 and 149 cm (Welch 2004). Variety *spiciformis*, considered by some a form of variety *vaseyana* (*A. tridentata* var. *vaseyana* f. *spiciformis*), occupies the highest elevation range (2800-3250 m) of the big sagebrush varieties and is known to occur on high mountain slopes in British Columbia and all western states except Oregon, Arizona, and New Mexico (Shultz 2006; Welch 2005). Across the study area, variety *vaseyana* is the most common variety of big sagebrush, and the remainder of the discussion will include specific information regarding *Artemisia tridentata* var. *vaseyana*. However, some information is general to big sagebrush (*A. tridentata*), and the terms “big sagebrush complex” or “big sagebrush” will be used when discussing this more general information.

On the east slope of the WRR in Wyoming, mountain big sagebrush occurs between roughly 2000 and 3000 m (Massatti 2007). Mountain big sagebrush is most successful on deep, well-drained, medium- to coarse-textured soils with low concentrations of salts (Welch 2005). Soil pH tends to range between slightly acidic to slightly alkaline with some strongly alkaline soils derived from calcareous parent materials (Johnson 2000). Mountain big sagebrush occurs across a wide range of soil textures but is most often found on loams or sandy-loams with high amounts of coarse fragments (35–70%) (Welch 2005). Mountain big sagebrush occurs on a variety of substrate types, including granite, rhyolite, andesite, argillite, basalt, greenstone, sandstone, limestone, shale, siltstone, dolomite, granodiorite, gneiss, mixed glacial till, and mixed alluvium (Johnson 2004; Svalberg 1997; Tweit and Houston 1980). The type of substrate appears to be less important than soil texture and depth. Mountain big sagebrush occurs most often in moderately deep (50–100 cm) to deep (>100 cm) colluvial, glacial, or alluvial soils and occasionally on shallow, residual soils where it is often reduced in stature. Mountain big sagebrush is intolerant of soil saturation. However, it can be found growing in moderately well-drained to well-drained soils on stream terraces (Crowe and Clausnitzer 1997).

Mountain big sagebrush is a native, perennial, woody, evergreen shrub that reproduces by seed, and vegetatively by layering (Johnson 2000). Flowers bloom in late July through September and seeds mature in late September and October. The non-dormant, small, lightweight seeds are wind dispersed and germination success is increased by cold, moist conditions and exposure to sunlight. The roots of mountain big sagebrush range in length from 1.5 to 2.5 m, allowing it to meet some of its water requirements from water reserves deep below the soil surface (Welch 2005). Lateral roots occur approximately 30 cm below the soil surface and can radiate out from 1 to 1.5 m from the stem of plants. The shallow, lateral roots make effective use of soil moisture that accumulates in the upper soil profile from winter snow and spring rain as well as convective thunderstorms throughout the summer. Mountain big sagebrush roots form a symbiotic relationship with mycorrhizae fungi, which aid in the absorption of nutrients, especially phosphorus. A phenomenon referred to as “hydraulic lift” is associated with the big sagebrush complex. First observed by Richards and Caldwell (1987) for basin big sagebrush, hydraulic lift is a process by which water, deep in the soil profile, is transported to the upper soil profile via plant roots. The process is driven by a water potential gradient that reflects the daytime depletion of soil moisture due to evapotranspiration. The increased water in the upper surface horizons alleviates the water demands of shallow, lateral big sagebrush roots and other shallow rooted plants associated with big sagebrush communities.

Fire return intervals in mountain big sagebrush communities vary between 15 and 40 years (Johnson 2000) but may be as much as 50 to 100 years (Welch 2005). Fire return intervals below this range can lead to the exclusion of mountain big sagebrush, while fire suppression has led to greater fire return intervals and, subsequently, the encroachment of conifers, including Utah and Rocky Mountain junipers, Douglas-fir, and lodgepole pine, into mountain big sagebrush communities. Mountain big sagebrush is killed by even light severity fires and will not resprout from the root crown if the above ground portion of the plant is completely killed. Recolonization of burned sites is by seed. Plants may reach reproductive maturity within 3 to 5 years, but 15 to 20 years is required to fully re-establish a site (Bunting and others 1987). Germination success of mountain big sagebrush seeds on burned sites one year post-fire has been observed to be highly variable and a light heat treatment may increase germination success.

Prescribed fire is a common means of managing mountain big sagebrush communities (Bunting and others 1987). However, vegetative response to fire in mountain big sagebrush communities is complex and is highly dependent on geographic region, seasonality, and plant species composition. Pre-burn plant composition is one of the key factors in determining the response of mountain big sagebrush communities to prescribed fire. Managers should consider the fire ecology of species co-existing with mountain big sagebrush in order to better understand the consequences of prescribed burning in an area. The presence of exotic species, especially cheatgrass (*Bromus tectorum*), in burned areas can permanently alter the community composition and fire regimes of post-fire mountain big sagebrush communities. Extensive plant surveys of areas considered for prescribed burning should be conducted before and after burning in order to assess pre- and post-fire conditions of the burned area. Bunting and others (1987) and Welch and Criddle (2003) provided comprehensive reviews of management considerations in big sagebrush communities.

Mountain big sagebrush suffers from a number of pests and diseases (Welch 2005). Winter kill can occur in low snow years in populations of mountain big sagebrush that normally receive enough snow to entirely cover the plants, insulating them from extreme cold temperatures and desiccation from strong winter winds. Snow depth, as it relates to the duration of snowmelt in spring, is related to a fungus that can lead to loss of vigor and sometimes death of mountain big sagebrush in deep snow pack years (Nelson and Sturges 1986). The snowmold fungus, Ascomycete, thrives in the snow around mountain big sagebrush at temperatures near 0 ºC, and is most active in the spring during melt-off, infecting the foliage and fine stems. A fine balance exists for mountain big sagebrush between too little snow, resulting in mortality due to cold and desiccation, and too much snow, resulting in loss of vigor and death due to the snow mold fungus. Long-tailed, mountain, and meadow voles girdle mountain big sagebrush, causing extensive physical damage and death (Welch 2005). Black stem rust (*Puccinia tanaceti*) is a parasitic fungus whose fruiting bodies cause blackening of the inflorescence and results in defoliation, stunting of inflorescence, and inhibited floret development. Aphids can cause defoliation, leaf curling, and wilting of big sagebrush plants. The beetle, *Trirhabda pilosa*, is an obligate to big sagebrush and during heavy infestations can cause extensive defoliation and death of big sagebrush. Big sagebrush is host to a number of root parasitic plant species, including paintbrushes (*Castilleja* spp.), owl-clovers (*Orthocarpus* spp.), and broomrapes (*Orobanche* spp.). Welch (2005) provided a comprehensive review of the parasites and insect pests that attack big sagebrush.

Mountain big sagebrush is of low palatability to cattle but provides a highly nutritious and protein-rich browse for domestic sheep, elk, mule deer, pronghorn, and bighorn sheep (Johnson 2001). Sage grouse, dark eyed juncos, horned larks, and white-crowned sparrows feed directly on mountain big sagebrush (Welch and Criddle 2003). A variety of small mammals also feed on the foliage and bark of mountain big sagebrush, including deer mice, least chipmunk, Ord's kangaroo rat, Pika, sagebrush voles, western cottontail, western harvest mice, and whitetail jackrabbits. Fifty-two species of aphids feed on the big sagebrush complex, which, in turn, are predated by a variety of wasps, ants, bees, sawflies, and ladybird beetles (Welch and Criddle 2003). Big sagebrush is an important component of the diets of Mormon crickets and grasshoppers, which can sometimes lead to extensive defoliation. Welch (2005) provided a comprehensive review of the many mammalian, bird, and insect species that use big sagebrush for food and cover. Mountain big sagebrush has high value for rehabilitation of disturbed sites and is easily propagated from seed (Johnson 2000).

Mountain Big Sagebrush/Idaho Fescue, Shawmut Family Ecological Type

Artemisia tridentata var. *vaseyana*/*Festuca idahoensis*, Shawmut Family Ecological Type

ARTRV2/FEID, Shawmut Family ET

N = 4

Distribution

The mountain big sagebrush/Idaho fescue, Shawmut Family Ecological Type occurs in the study area within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from Squaw Creek southeast to Limestone Mountain. It is a component of map unit 15L.

Environment

Aspect: North-northeast [1], south-southwest [2], west-southwest [1].

Landforms and Landscape Position: Landslide deposits, footslopes, alluvial terraces.

Parent Materials: Colluvium.

Parent materials for this ecological type are siltstone or shale colluvium mixed with limestone colluvium. On slopes of the Amsden Formation, the characteristic red to purplish soil colors are imparted by the Horseshoe Shale member of the Amsden Formation, while calcareous influence on the soil stems from the Ranchester Limestone member. On slopes of the Gros Ventre Formation, the soils typically display yellow-greenish colors and high carbonate content. Parent materials on Gros Ventre Slopes are calcareous shales of the Wolsey and/or Park Shale members of the Gros Ventre Formation mixed with Gallatin Limestone and/or Bighorn Dolomite colluvium.

Bedrock: Cambrian Gros Ventre Shale, late Mississippian/early Pennsylvanian Amsden Siltstone.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 51 to 66 cm.

Additional environment data summaries are provided in Table 96.

Potential natural vegetation

The potential natural vegetation of this ecological type is mountain big sagebrush/Idaho fescue habitat type (Tweit and Houston 1980). The vegetation composition best represents the drier, lower elevation stands of the mountain big sagebrush/Idaho fescue habitat type described by Tweit and Houston (1980). Mountain big sagebrush forms a dense, low to moderately tall (≤1 m) shrub layer. Yellow rabbitbrush, antelope bitterbrush, Wyoming three-tip sagebrush, and western serviceberry may also occur but rarely at great abundance. Idaho fescue, bluebunch wheatgrass, and Sandberg bluegrass are the predominant grass species. Spike sedge and grassyslope sedge are low growing, densely tufted sedges that sometimes occurs in this type. Sticky purple geranium and red avens are absent from these drier, lower elevation stands. The forb layer resembles that of adjacent mountain big sagebrush/bluebunch wheatgrass communities. Hoary or arrowleaf balsamroots and timber milkvetch are always present and may occur at high abundance. Other common herbaceous species include many-flowered phlox, oblongleaf bluebells, Holboell's rockcress, sulphur-flower buckwheat, northern Idaho biscuitroot, bigleaf lupine, tapertip hawksbeard, and ballhead sandwort. Table 97 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the ARTRV2/FEID, Shawmut Family ET are deep and carbonate rich with a high degree of soil development, including strong clay illuviation into subsurface soil horizons. A typical soil includes an A/Bt-Btk/Bk horizonation. Diagnostic soil horizons include a mollic epipedon (avg. 31 cm thick), a thick argillic horizon (avg. 58 cm thick), and a calcic horizon (avg. 46 cm thick). Particle size class included loamy-skeletal [3] and fine-loamy [1]. The soils were classified as clay-rich Typic Argiustolls [3] and Pachic Argiustolls [1].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Typic Argiustolls

A1—0 to 7 cm: dark brown (7.5YR 3/3) loam, very dark brown (7.5YR 2/2), moist; 51% sand; 15% clay; weak very fine granular structure; loose, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 11% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 6.0; abrupt smooth boundary.

A2—7 to 21 cm: brown (7.5YR 4/3) fine sandy loam, dark brown (7.5YR 3/2), moist; 56% sand; 16% clay; moderate medium granular structure, and moderate medium subangular blocky structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 3% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 10% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; slightly acid, pH 6.1; abrupt smooth boundary.

Bt—21 to 39 cm: reddish brown (5YR 4/4) very cobbly sandy clay loam, dark reddish brown (5YR 3/3), moist; 47% sand; 25% clay; moderate medium subangular blocky structure, and moderate fine subangular blocky structure; friable, very hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; clay films on surfaces along pores and clay films on surfaces along root channels and 31% distinct clay films on faces of peds; carbonate, finely disseminated throughout; 1% flat angular indurated 380- to 600-mm unspecified fragments and 10% flat angular indurated 150- to 380-mm unspecified fragments and 11% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments; very slight effervescence; neutral, pH 6.7; clear wavy boundary.

Bk—39 to 74 cm: very pale brown (10YR 7/3) very cobbly sandy clay loam, yellowish brown (10YR 5/4), moist; 49% sand; 28% clay; moderate medium subangular blocky structure, and moderate fine subangular blocky structure; friable, hard, moderately sticky, moderately plastic; common fine roots and common medium roots and common very fine roots; common fine and many very fine pores; 98% carbonate nodules around rock fragments; 2% flat angular indurated 380- to 600-mm unspecified fragments and 13% flat angular indurated 150- to 380-mm unspecified fragments and 17% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 21% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; slightly alkaline, pH 7.7; clear wavy boundary.

CBk—74 to 102 cm: light gray (10YR 7/2) extremely gravelly sandy clay loam, light yellowish brown (10YR 6/4), moist; 53% sand; 29% clay; massive; very friable, moderately hard, moderately sticky, moderately plastic; common medium roots and common very fine roots; common medium and many very fine pores; 99% carbonate nodules around rock fragments; 3% flat angular indurated 380- to 600-mm unspecified fragments and 14% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 19% flat angular indurated 150- to 380-mm unspecified fragments and 38% nonflat subrounded indurated 2- to 75-mm unspecified fragments; violent effervescence; slightly alkaline, pH 7.7.

Ecology

The mountain big sagebrush/Idaho fescue, Shawmut family ET is strongly tied to lower slope positions in soils derived in part from siltstone and shale due to higher available soil moisture relative to soils derived from limestone and dolomite on upper slope positions. Moisture availability tends to be more important than soil parent material in determining the distribution of Idaho fescue (Zouhar 2000). However, soil parent material influences soil texture, which is an important factor influencing AWC of soils. Siltstone and shale are fine-grained sedimentary rocks that weather to form clay-rich soils that have high available water-holding capacity. Soil moisture is further increased by the accumulation of water at these lower slope positions due to gravity.

Management considerations

The ARTRV2/FEID, Shawmut Family ET provides excellent foraging opportunities for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Idaho fescue is a highly preferred forage species of wild and domestic ungulates (Zouhar 2000). Protein content is typically highest in the spring and decreases throughout the growing season. Light to moderate grazing can enhance Idaho fescue grasslands. However, Idaho fescue is only moderately tolerant of grazing and is considered a grazing decreaser under heavy grazing. The productive nature of these communities combined with fire suppression has resulted in an abundance of fuels in this ET. Invasive plants, including cheatgrass, also tend to be associated with roads that cut through this ET. Fires in the ARTRV2/FEID, Shawmut Family ET are expected to be severe. Idaho fescue and mountain big sagebrush tend to respond negatively to severe burns (Johnson 2000; Zouhar 2000), requiring at least 10 to 20 years to recover. Land managers planning prescribed burns of upslope sagebrush communities should avoid burning the ARTRV2/FEID, Shawmut Family ET in order to reduce the risk of spreading invasive plants.

Similar ecological types

Ecological Type 1

Type: Mountain big sagebrush/Idaho fescue, Kiev Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The Kiev Family ET differs from the Shawmut Family ET in that the former features fine-loamy particle size and little to no subsurface clay accumulations, while the later features loamy-skeletal particle size and strong illuviation of clay into subsurface horizons.

Ecological Type 2

Type: Mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET

Floristic differences: The two types differ floristically in that the PNV of the Shawmut Family ET is the mountain big sagebrush/Idaho fescue habitat type, while the PNV of the Winspect Family ET is the mountain big sagebrush/bluebunch wheatgrass habitat type.

Environmental differences: The two types differ environmentally in that the Shawmut Family ET occurs on lower slope positions and alluvial terraces, while the Winspect Family occurs on upper slope positions.

Table 96—Summary of environmental variables for the ARTRV2/FEID, Shawmut Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,489	2,292	2,700
Slope (%)	18	7	25
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	574	510	657
Degree days	17,920	15,410	20,070
Frost-free days	20.4	19.1	21.3
Site water balance (mm/year)	-333	-377	-226
Average annual temperature (°C)	2.4	1.4	3.2
Total annual potential evapotranspiration (mm)	689	606	738
Summer radiation (KJ)	20,740	20,220	20,990
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	46	26	64
Clay (% in particle size control section)	27	24	33
pH (in particle size control section)	7.5	7.2	7.7
Available water capacity (mm/m)	88	66	123
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	16	10	20
Exposed bedrock	0	0	0
Gravel	12	3	20
Cobble	6	0	10
Stones	2	0	5
Boulders	1	0	3
Litter	11	1	30
Wood	0	0	0
Moss and lichen	1	0	2
Basal vegetation	43	30	70
Water	0	0	0

Table 97—Constancy/cover table for common plant species occurring in the ARTRV2/FEID, Shawmut Family ET.

Characteristic	Species		Con	Cov	Min	Max
			Percent			
Shrubs:						
AMAL2	*Amelanchier alnifolia*	western serviceberry	50	1	1	1
ARTRR4	*Artemisia tripartita*	Wyoming three-tip sagebrush	75	2	1	3
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	42	20	65
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	75	1	1	1
PUTR2	*Purshia tridentata*	antelope bitter-brush	50	1	1	1
Forbs:						
ACMIL3	*Achillea millefolium* var. *lanulosa*	western yarrow	75	2	1	3
AGGL	*Agoseris glauca*	pale agoseris	75	2	1	3
ANUM	*Antennaria umbrinella*	umber pussy-toes	75	2	1	5
ASMI9	*Astragalus miser*	timber milkvetch	100	5	1	15
BAIN	*Balsamorhiza incana*	hoary balsamroot	50	9	3	15
BASA3	*Balsamorhiza sagittata*	arrowleaf balsamroot	50	2	1	3
BOEHOL	*Boechera holboellii*	Holboell's rockcress	75	1	1	1
CAPA25	*Castilleja pallescens*	palish Indian-paintbrush	50	2	1	3
CEAR4	*Cerastium arvense*	field chickweed	50	3	1	5
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	50	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	75	1	1	1
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	50	3	1	5
DOCO	*Dodecatheon conjugens*	slimpod shooting star	50	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	75	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	50	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	100	2	1	3
LERE7	*Lewisia rediviva*	bitterroot	50	1	1	1
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	75	1	1	1
LUPO2	*Lupinus polyphyllus*	bigleaf lupine	75	2	1	3
MEVI4	*Mertensia viridis*	oblongleaf bluebells	75	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	50	3	1	5
PHMU3	*Phlox multiflora*	many-flowered phlox	100	2	1	5
SEIN4	*Sedum integrifolium*	ledge stonecrop	50	2	1	3
TAOF	*Taraxacum officinale*	common dandelion	75	2	1	3
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	4	3	5
FEID	*Festuca idahoensis*	Idaho fescue	100	20	15	25
KOMA	*Koeleria macrantha*	prairie junegrass	50	3	1	5
LEKI2	*Leucopoa kingii*	spike-fescue	50	2	1	3
POSE	*Poa secunda*	Sandberg bluegrass	100	11	5	20
Graminoids:						
CANA2	*Carex nardina*	spike sedge	50	1	1	1
CAREX	*Carex*	sedge	50	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Mountain Big Sagebrush/Idaho Fescue, Ledgefork Family Ecological Type

Artemisia tridentata var. *vaseyana*/ *Festuca idahoensis*, Ledgefork Family Ecological Type

ARTRV2/FEID, Ledgefork Family ET

N = 3

Distribution

The mountain big sagebrush/Idaho fescue, Ledgefork Family Ecological Type occurs in the northern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs to the south and east of Louis Lake in a network of diabasic gabbro dikes that have intruded into the Louis Lake Pluton (Bayley and others 1973) and on gently undulating hills formed from Louis Lake granodiorite located directly to the west of the South Pass Granite-Greenstone Belt. This ET is a component of map unit 309L.

Environment

Aspect: Southwest [2], west-southwest [1].

Landforms and Landscape Position: Diabasic gabbro dikes and gentle, undulating hills. Lower backslopes and footslopes on dikes, all slope positions on hills.

Parent Materials: Diabasic gabbro colluvium over Louis Lake Granodiorite residuum. Louis Lake Granodiorite residuum.

Bedrock: Louis Lake Granodiorite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation is 61 cm.

Additional environment data summaries are provided in Table 98.

Potential natural vegetation

The potential natural vegetation of this ecological type includes the mountain big sagebrush/Idaho fescue habitat type. Mountain big sagebrush is reduced in stature due to the shallow to moderately deep, droughty soils. The herbaceous layer is scant and relatively unproductive when compared to sagebrush communities growing on calcareous parent materials. Idaho fescue and Sandberg bluegrass are the predominant herbaceous species. Idaho fescue achieves the highest cover on sheltered, concave slope positions and concave microsites. Common herbaceous species include timber milkvetch, ballhead sandwort, cutleaf daisy, cushion buckwheat, bitterroot, Hood's phlox, northern Idaho biscuitroot, lance-leaved stonecrop, and Sandberg bluegrass. Bare ground and gravels are prevalent at the soil surface. Table 99 provides a summary of species constancy and cover for this ecological type.

Soils

The soils at these sites were all shallow to moderately deep to grus (Cr-horizon), a type of partially decomposed bedrock that has weathered to gravel-sized rock fragments. The grus was dense, prohibitive to root penetration, and extremely low in clay. Soils occurring on or near dikes, and derived from diabasic gabbro colluvium over granodiorite residuum had an average pH higher than ~6.0, reflecting the greater concentration of cations (Ca^{2+}, Mg^{2+}) in the diabasic gabbro.

Soils in the ARTRV2/FEID, Ledgefork Family ET were shallow to moderately deep and gravelly, with a low to moderate degree of soil development, moderate to high coarse fragments (45–71%, avg. 61%), and low to moderate amounts of clay (4–19%, avg. 10%). A typical soil features an A/Bw-Bt/C/Cr-R horizonation. Distinguishing soil horizons include mollic epipedon (avg. 22 cm thick), and shallow to moderately deep paralithic or lithic contact (avg. 57 cm thick). The soils were sandy-skeletal Typic Haplocryolls [2] and loamy-skeletal Lithic Haplocryolls [1].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed Typic Haplocryolls

A1—0 to 8 cm: very dark brown (10YR 2/2) very gravelly coarse sandy loam, dark grayish brown (10YR 4/2), dry; 70% sand; 9% clay; moderate coarse subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 3% 76- to 250-mm unspecified fragments and 10% 251- to 600-mm unspecified fragments and 28% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; neutral, pH 6.6; clear wavy boundary.

A2—8 to 27 cm: dark brown (10YR 3/3) very gravelly coarse sandy loam, brown (10YR 4/3), dry; 72% sand; 8% clay; moderate coarse subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 4% 76- to 250-mm unspecified fragments and 15% 251- to 600-mm unspecified fragments and 34% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.5; clear smooth boundary.

Bw—27 to 41 cm: brown (10YR 4/3) very gravelly loamy coarse sand, brown (10YR 5/3), dry; 82% sand; 5% clay; weak medium subangular blocky structure, and moderate fine granular structure; friable, slightly hard, nonsticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 9% 76- to 250-mm unspecified fragments and 42% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.5; clear wavy boundary.

CB—41 to 72 cm: variegated; extremely gravelly coarse sand, pale brown (10YR 6/3), dry; 88% sand; 4% clay; weak fine subangular blocky structure; very friable, slightly hard, nonsticky, nonplastic; common medium roots and common very fine roots; common medium and common very fine pores; 69% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.3; gradual broken boundary.

2C—72 to 97 cm: variegated; extremely gravelly coarse sand; 90% sand; 3% clay; single grain; loose, nonsticky, nonplastic; common very fine roots; common very fine pores; 81% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.2; abrupt smooth boundary.

2Cr—97 to 112 cm: variegated; 94% sand; 4% clay; single grain; loose, nonsticky, nonplastic; common very fine roots; common very fine pores; 1% 76- to 250-mm unspecified fragments and 90% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; slightly acid, pH 6.2.

Ecology

The ARTRV2/FEID, Ledgefork Family ET, with the exception of the dominant sagebrush species, is similar floristically to the ARTRR4/FEID, Ledgefork Family ET. However, the two ETs inhabit distinctly different slope positions depending on the dominant sagebrush species. Mountain big sagebrush is most successful on deep, well-drained, medium- to coarse-textured soils and is most often found on loams or sandy-loams with high amounts of coarse fragments (35-70%) (Welch 2005). Unlike the Wyoming three-tip sagebrush, which is adapted to cold, windswept, xeric conditions typical of upper backslope, shoulder, and summit positions, mountain big sagebrush in Wyoming has been shown to be associated with lower, less exposed slope positions (Burke and others 1989).

Management considerations

The ARTRV2/FEID, Ledgefork Family ET provides important foraging grounds for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer.

The unproductive nature of these communities results in a minimal accumulation of fuels. Fires in the ARTRV2/FEID, Ledgefork Family ET, especially later in the season, are expected to be rapid and of low to moderate intensity, resulting in minimal damage to sagebrush or Idaho fescue. Response of Idaho fescue and mountain big sagebrush is generally positive following low to moderate severity burns (Johnson 2000; Zouhar 2000).

Similar ecological types

Ecological Type 1

Type: Wyoming three-tip sagebrush/Idaho fescue, Ledgefork Family ET

Floristic differences: The two types differ floristically in the dominant sagebrush, including Wyoming three-tip sagebrush in the ARTRR4/FEID, Ledgefork Family ET and mountain big sagebrush in the ARTRV2/FEID, Ledgefork Family ET.

Environmental differences: The types differ environmentally in that the ARTRR4/FEID, Ledgefork Family ET occurs on shoulders and upper backslopes, while the ARTRV2/FEID, Ledgefork Family ET occurs on lower backslopes and footslopes and areas of gentle topography.

Ecological Type 2

Type: Mountain big sagebrush/Idaho fescue, Corbly 166D Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Corbly 166D Family ET occurs in the South Pass Granite-Greenstone belt, while the Ledgefork Family ET occurs elsewhere.

Ecological Type 3

Type: Mountain big sagebrush/Idaho fescue, Lithic Argiustolls ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Lithic Argiustolls ET occurs in the South Pass Granite-Greenstone belt, while the Ledgefork Family ET occurs elsewhere.

Table 98—Summary of environmental variables for the ARTRV2/FEID, Ledgefork Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,655	2,591	2,768
Slope (%)	4	2	5
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	609	605	613
Degree days	16,310	16,290	16,320
Frost-free days	19.6	19.5	19.7
Site water balance (mm/year)	-340	-343	-336
Average annual temperature (°C)	1.7	1.7	1.7
Total annual potential evapotranspiration (mm)	647	647	647
Summer Radiation (KJ)	20,620	20,620	20,620
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	61	45	71
Clay (% in particle size control section)	10	4	19
pH (in particle size control section)	5.5	4.7	6.3
Available water capacity (mm/m)	25	20	32
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	13	5	20
Exposed bedrock	0	0	0
Gravel	25	20	30
Cobble	1	1	1
Stones	2	1	3
Boulders	1	0	3
Litter	13	5	20
Wood	0	0	0
Moss and lichen	4	3	5
Basal vegetation	43	20	65
Water	0	0	0

Table 99—Constancy/cover table for common plant species occurring in the ARTRV2/FEID, Ledgefork Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	27	15	40
Forbs:						
ANUM	*Antennaria umbrinella*	umber pussy-toes	67	1	1	1
ASMI9	*Astragalus miser*	timber milkvetch	67	4	3	5
ERCO24	*Eremogone congesta*	ballhead sandwort	67	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	67	1	1	1
EROC	*Erigeron ochroleucus*	buff fleabane	67	2	1	3
EROV	*Eriogonum ovalifolium*	cushion buckwheat	67	1	1	1
GETR	*Geum triflorum*	red avens	67	1	1	1
LERE7	*Lewisia rediviva*	bitterroot	67	1	1	1
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	67	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	67	3	3	3
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	67	2	1	3
Grasses:						
FEID	*Festuca idahoensis*	Idaho fescue	100	13	10	15
POSE	*Poa secunda*	Sandberg bluegrass	67	20	10	30

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Mountain Big Sagebrush/Idaho Fescue, Corbly 166D Family Ecological Type

Artemisia tridentata var. *vaseyana*/ *Festuca idahoensis*, Corbly 166D Family Ecological Type

ARTRV2/FEID, Corbly 166D Family ET

N = 4

Distribution

The mountain big sagebrush/Idaho fescue, Corbly 166D Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs in the South Pass Granite-Greenstone Belt, and is a component of join unit 166D.

Environment

Aspect: North-northwest [2], southeast [1], southwest [1].

Landforms and Landscape Position: Diabasic gabbro dikes and gentle, undulating hills. Shoulders and backslopes.

Parent Materials: Residuum. Diabasic gabbro, Louis Lake Granodiorite, granodiorite-amphibolite gneiss, granodiorite-graywacke gneiss, migmatite, and granite.

Bedrock: This ET is located in the South Pass Greenstone Belt and contains a complex of igneous intrusive and metasedimentary rocks, including diabasic gabbro, Louis Lake Granodiorite, and migmatite, graywacke gneiss, amphibolite, granite, and granodiorite of the Gneiss Belt, a border zone of contact metamorphism within the Greenstone Belt (Bayley and others 1973; Hausel1988, 1991).

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation ranges from 60 to 62 cm.

Additional environment data summaries are provided in Table 100.

Potential natural vegetation

The potential natural vegetation of this ecological type is the mountain big sagebrush/Idaho fescue habitat type. Mountain big sagebrush is reduced in stature due to the moderately deep, rocky soils. Yellow rabbitbrush is commonly associated with this type. The herbaceous layer is scant and relatively unproductive when compared to sagebrush communities growing on calcareous parent materials. Idaho fescue and Sandberg bluegrass are the predominant herbaceous species. Succulent and cushion plants, including lance-leaved stonecrop, bitterroot, Hood's and many-flowered phlox, cushion and sulphur-flower buckwheat, and umber pussy-toes, are common to this ecological type and indicative of the windy, drought-ridden conditions typical at these sites. Other common herbaceous species include bluebunch wheatgrass, timber milkvetch, and oblongleaf bluebells. Gravels and cobbles are prevalent at the soil surface, at times forming patches of erosion pavement. Table 101 provides a summary of species constancy and cover for this ecological type.

Soils

In general, soils in this area tended to have average weighted pH higher than ~6.0, reflecting the greater concentration of cations (Ca^{2+}, Mg^{2+}) in the diabasic gabbro, metasedimentary, and ultramafic rocks. Soils formed in Louis Lake Granodiorite were shallow to moderately deep to grus (Cr-horizon), a type of partially decomposed bedrock that has weathered to gravel-sized rock fragments. The grus was dense, prohibitive to root penetration, and extremely low in clay. A typical soil features an A/Bw/C-Cr/R horizonation. Diagnostic soil horizons include a thick mollic epipedon (avg. 42 cm thick), paralithic materials (avg. 16 cm thick), and moderately deep lithic contact (avg. 86 cm depth). Soils were sandy-skeletal Entic Haplustolls [1] and Pachic Haplustolls [1].

Soils derived from metasedimentary rocks of the Gneiss Belt (Hausel 1988) were moderately deep to fractured bedrock and high in coarse fragments (>60%). Clay minerals were generally low to moderate in abundance (≤15%). A typical soil features an A/C-Cr/R horizonation. Diagnostic soil horizons include a mollic epipedon (avg. 25-cm thick), and moderately deep lithic contact (avg. 77-cm depth). Particle size class included sandy-skeletal [1], and loamy-skeletal [1]. Soils were Entic Haplustolls [2].

Typical pedon description

Soil Classification: Sandy-skeletal, mixed, frigid Entic Haplustolls

A—0 to 9 cm: very dark grayish brown (10YR 3/2) fine gravelly coarse sand, very dark gray (10YR 3/1), moist; 91% sand; 4% clay; weak fine granular structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and many very fine pores; 23% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.3; abrupt wavy boundary.

AB—9 to 32 cm: dark yellowish brown (10YR 4/4) fine gravelly loamy sand, dark brown (10YR 3/3), moist; 88% sand; 9% clay; moderate medium granular structure, and weak coarse subangular blocky structure; very friable, slightly hard, slightly sticky, nonplastic; many fine roots and common medium roots and many very fine roots; many fine and common medium and many very fine pores; 24% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.4; clear smooth boundary.

Bw—32 to 60 cm: light yellowish brown (10YR 6/4) medium gravelly sand, dark yellowish brown (10YR 4/4), moist; 90% sand; 8% clay; moderate medium subangular blocky structure, and moderate medium granular structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 41% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid,pH 5.5; abrupt smooth boundary.

Cr—60 to 79 cm: brownish yellow (10YR 6/6) extremely cobbly coarse sand, dark yellowish brown (10YR 4/6), moist; 94% sand; 3% clay; single grain; loose, slightly sticky, nonplastic; common fine roots and common medium roots; common fine and common medium pores; 23% 2- to 75-mm unspecified fragments and 42% 76- to 250-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.5; abrupt smooth boundary.

R—79 cm: bedrock.

Ecology

The ARTRV2/FEID, Corbly 166D Family ET is similar in many ways to the ARTRV2/FEID, Lithic Argiustolls ET, both occurring most often on hot, dry south-facing slopes and convex slope positions, adjacent to the PICO Series, Corbly Family ET, which occurs on cooler, more mesic north-facing slopes and concave slope positions. However, the ARTRV2/FEID, Corbly 166D Family ET inhabits less exposed slope positions and relatively deeper soils than the ARTRV2/FEID, Lithic Argiustolls ET. The reduced stature of mountain big sagebrush is most likely related to the moderately deep, droughty soils. Snow accumulation is low to moderate (<50 cm) at these sites.

Management considerations

The ARTRV2/FEID, Corbly 166D Family ET provides important foraging grounds for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer. The unproductive nature of these communities results in a minimal accumulation of fuels. Fires in the ARTEM/FEID, Ledgefork Family ET, especially later in the season, are expected to be rapid and of low to moderate intensity, resulting in minimal damage to sagebrush or Idaho fescue. Response of Idaho fescue and Mountain big sagebrush is generally positive following low to moderate severity burns (Johnson 2000; Zouhar 2000).

Idaho fescue is a highly preferred forage species of wild and domestic ungulates (Zouhar 2000). Protein content is typically highest in the spring and decreases throughout the growing season. Light to moderate grazing can enhance Idaho fescue grasslands. However, Idaho fescue is only moderately tolerant of grazing and is considered a grazing decreaser under heavy grazing. The degree of grazing pressure that Idaho fescue can sustain depends on the interaction between wildlife and livestock using the range, plant phenology, type of grazing system used, competition from associated vegetation, plant vigor, and site conditions. Heavy grazing reduces the ability of Idaho fescue to compete with non-native species.

Simlar Ecological Types

Ecological Type 1

Type: Mountain big sagebrush/Idaho fescue, Ledgefork Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Corbly 166D Family ET occurs in the South Pass Granite-Greenstone belt, while the Ledgefork Family ET occurs elsewhere.

Ecological Type 2

Type: Mountain big sagebrush/Idaho fescue, Lithic Argiustolls ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Corbly 166D Family ET features moderately deep soils, while the Lithic Argiustolls ET features shallow soils.

Ecological Type 3

Type: Mountain big sagebrush/Idaho fescue, Corbly 351L Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Corbly 166D Family ET occurs in the South Pass Granite-Greenstone belt and features soils formed from metasedimentary and metamorphic residuum, while the Corbly 351L Family ET occurs in upper section of Sinks Canyon and features soils formed from granitic glacial till.

Table 100—Summary of environmental variables for the ARTRV2/FEID, Corbly 166D Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,601	2,570	2,623
Slope (%)	8	1	15
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	606	599	615
Degree days	16,430	16,260	16,690
Frost-free days	19.6	19.5	19.7
Site water balance (mm/year)	-339	-353	-318
Average annual temperature (°C)	1.8	1.7	1.9
Total annual potential evapotranspiration (mm)	638	613	650
Summer radiation (KJ)	20,350	19,910	20,610
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	69	60	78
Clay (% in particle size control section)	8	4	15
pH (in particle size control section)	6.3	5.4	7.3
Available water capacity (mm/m)	21	13	30
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	9	5	15
Exposed bedrock	1	0	2
Gravel	30	15	55
Cobble	2	0	5
Stones	2	0	3
Boulders	2	0	5
Litter	11	5	15
Wood	2	0	5
Moss and lichen	2	0	5
Basal vegetation	35	20	65
Water	0	0	0

Table 101—Constancy/cover table for common plant species occurring in the ARTRV2/FEID, Corbly 166D Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	29	20	45
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	50	2	1	3
Forbs:						
ANUM	*Antennaria umbrinella*	umber pussy-toes	50	1	1	1
ASMI9	*Astragalus miser*	timber milkvetch	100	3	1	5
BAIN	*Balsamorhiza incana*	hoary balsamroot	50	2	1	3
CAPA25	*Castilleja pallescens*	palish Indian-paintbrush	75	1	1	1
EROC	*Erigeron ochroleucus*	buff fleabane	50	1	1	1
EROV	*Eriogonum ovalifolium*	cushion buckwheat	50	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	75	2	1	3
GETR	*Geum triflorum*	red avens	50	1	1	1
LERE7	*Lewisia rediviva*	bitterroot	75	1	1	1
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	75	2	1	3
MEVI4	*Mertensia viridis*	oblongleaf bluebells	100	2	1	3
PHHO	*Phlox hoodii*	Hood's phlox	75	3	3	3
PHMU3	*Phlox multiflora*	many-flowered phlox	75	2	1	5
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	100	2	1	3
Grasses:						
ELEL5	*Elymus elymoides*	squirreltail	75	2	1	3
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	75	5	1	10
FEID	*Festuca idahoensis*	Idaho fescue	100	15	5	20
POSE	*Poa secunda*	Sandberg bluegrass	100	10	5	15

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Mountain Big Sagebrush/Idaho Fescue, Lithic Argiustolls Ecological Type

Artemisia tridentata var. *vaseyana*/*Festuca idahoensis*, Lithic Argiustolls Ecological Type

ARTRV2/FEID, Lithic Argiustolls ET

N = 3

Distribution

The mountain big sagebrush/Idaho fescue, Lithic Argiustolls Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs in the South Pass Granite-Greenstone Belt, and is a component of join unit 166D.

Environment

Aspect: South-southwest [1], west [1], west-northwest [1].

Landforms and Landscape Position: Diabasic gabbro dikes and gentle, undulating hills. Summits and shoulders.

Parent Materials: Residuum. Schist, serpentinite, granodiorite-amphibolite gneiss, granodiorite-graywacke gneiss, diabasic gabbro, migmatite, and granite.

Bedrock: This ET is located in the South Pass Greenstone Belt, and bedrock contains a complex of igneous intrusive, metasedimentary, and ultramafic rocks, including orthoamphibolite, schist, and serpentinite of the Diamond Springs Formation, diabasic gabbro, and migmatite, graywacke gneiss, amphibolite, granite, and granodiorite of the Gneiss Belt, a border zone of contact metamorphism within the Greenstone Belt (Bayley and others 1973; Hausel 1988, 1991).

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation ranges from 60 to 61 cm.

Additional environment data summaries are provided in Table 102.

Potential natural vegetation

The potential natural vegetation of this ecological type is the mountain big sagebrush/Idaho fescue habitat type. Mountain big sagebrush is reduced in stature due to the shallow, rocky soils. Yellow rabbitbrush is commonly associated with this type. The herbaceous layer is scant and relatively unproductive when compared to sagebrush communities growing on calcareous parent materials. Idaho fescue and Sandberg bluegrass are the predominant herbaceous species. Succulent and cushion plants, including lance-leaved stonecrop, bitterroot, Hood's and many-flowered phlox, cushion buckwheat, umber pussytoes, and stemless mock goldenweed, are common to this ecological type, and indicative of the windy, drought-ridden conditions typical at these sites. Other common herbaceous species include bluebunch wheatgrass, timber milkvetch, oblongleaf bluebells, nodding onion, and hoary balsamroot. The majority of the soil surface is composed of an extensive erosion pavement. Table 103 provides a summary of species constancy and cover for this ecological type.

Soils

In general, soils in this ET tended to have average weighted pH higher than ~6.0, reflecting the greater concentration of cations (Ca^{2+}, Mg^{2+}) in the diabasic gabbro, metasedimentary, and ultramafic rocks. Soils were shallow to bedrock, high pH (>6.0) and high coarse fragments (avg. 72%) with low to moderate amounts of clay minerals (12–21%, avg. 18%). A typical soil features an A/Bw-C/R horizonation. Diagnostic soil characteristics include a relatively thick mollic epipedon (avg. 30 cm thick) and shallow lithic contact (avg. 42 cm depth). Soils were sandy-skeletal Lithic Argiustolls and loamy-skeletal Lithic Haplustolls.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Lithic Argiustolls

A—0 to 5 cm: brown (10YR 4/3) cobbly coarse sandy loam, very dark grayish brown (10YR 3/2), moist; 75% sand; 12% clay; weak very fine granular structure; very friable, soft, slightly sticky, nonplastic; many fine roots and few medium roots and many very fine roots; many fine and few medium and many very fine pores; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 12% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; slightly acid, pH 6.2; clear wavy boundary.

BA—5 to 19 cm: brown (10YR 5/3) stony coarse sandy loam, dark brown (10YR 3/3), moist; 77% sand; 16% clay; weak fine subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common very fine and fine roots and common medium roots; common very fine and fine and common medium pores; 2% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 16% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 16% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; moderately acid, pH 5.9; clear wavy boundary.

Bt—19 to 44 cm: 2% light yellowish brown (10YR 6/4) and 1% yellowish brown (10YR 5/4) extremely stony sandy clay loam, 2% dark yellowish brown (10YR 4/4) and 1% brown (10YR 4/3), moist; 71% sand; 21% clay; weak very fine subangular blocky structure; friable, slightly hard, moderately sticky, slightly plastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 1% patchy faint clay films on surfaces along root channels and 1% patchy faint clay films between sand grains and 1% patchy faint clay films on rock fragments; 7% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 26% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 40% nonflat subrounded indurated 600- to 3000-mm unspecified fragments; noneffervescent; moderately acid, pH 6.0; clear wavy boundary.

R1—44 to 81 cm: light yellowish brown (10YR 6/4) extremely stony fine sandy loam, dark yellowish brown (10YR 4/4), moist; 78% sand; 17% clay; weak very fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and few medium roots and common very fine roots; common fine and few medium and common very fine pores; 8% nonflat subrounded indurated 76- to 250-mm unspecified fragments and 27% nonflat subrounded indurated 2- to 75-mm unspecified fragments and 49% nonflat subrounded indurated 250- to 600-mm unspecified fragments; noneffervescent; moderately acid, pH 6.0; clear wavy boundary.

R2—81cm: light yellowish brown (10YR 6/4) stony sand, fragmental material, dark yellowish brown (10YR 4/4), moist; 91% sand; 5% clay; single grain; loose, nonsticky, nonplastic; few fine roots and common very fine roots; few fine and common very fine pores; 32% nonflat subrounded indurated 250- to 600-mm unspecified fragments and 61% nonflat subrounded indurated 2- to 75-mm unspecified fragments; noneffervescent; moderately acid, pH 6.0; colors: dry and moist are variegated.

Ecology

The ARTRV2/FEID, Lithic Argiustolls ET is similar in many ways to the ARTRV2/FEID, Corbly 166D Family ET, both occurring most often on hot, dry, south-facing slopes and convex slope positions adjacent to the PICO Series, Corbly Family ET, which occurs on cooler, more mesic north-facing slopes and concave slope positions. However, the ARTRV2/FEID, Lithic Argiustolls ET inhabits more exposed slope positions and shallower soils than the ARTRV2/FEID, Corbly 166D Family ET. Mountain big sagebrush is even more reduced in stature and cushion plants make up a greater majority of the herbaceous layer. These sites are extremely windy, as evidenced by the erosion pavement of gravels and the shallow to moderately deep bedrock limits root penetration to the upper 50 cm of soil. These summit and shoulder positions are typically blown free of snow during the winter months resulting in very little protection from extremely cold temperatures, wind chill effects, and physical abrasion from snow and ice particles.

Management considerations

The ARTRV2/FEID, Lithic Argiustolls ET provides important foraging grounds for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide important forage in the spring and early summer. The unproductive nature of these communities results in a minimal accumulation of fuels. Fires in the ARTRV2/FEID, Lithic Argiustolls Family ET, especially later in the season, are expected to be rapid and of low to moderate intensity, resulting in minimal damage to sagebrush or Idaho fescue. Response of Idaho fescue and Mountain big sagebrush is generally positive following low to moderate severity burns (Johnson 2000; Zouhar 2000).

Similar ecological types

Ecological Type 1

Type: Mountain big sagebrush/Idaho fescue, Ledgefork Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Lithic Argiustolls ET occurs in the South Pass Granite-Greenstone belt, while the Ledgefork Family ET occurs elsewhere.

Ecological Type 2

Type: Mountain big sagebrush/Idaho fescue, Corbly 166D Family ET

Floristic differences: The two types are very similar floristically.

Environmental differences: The two types differ environmentally in that the Corbly 166D Family ET features moderately deep soils, while the Lithic Argiustolls ET features shallow soils.

Table 102—Summary of environmental variables for the ARTRV2/FEID, Lithic Argiustolls ET.

General environment:	Average	Min	Max
Elevation (m)	2,600	2,596	2,602
Slope (%)	7	3	13
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	607	602	609
Degree days	16,360	16,190	16,580
Frost-free days	19.6	19.5	19.7
Site water balance (mm/year)	-342	-363	-323
Average annual temperature (°C)	1.7	1.6	1.8
Total annual potential evapotranspiration (mm)	642	628	653
Summer radiation (KJ)	20,440	20,320	20,560
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	72	64	79
Clay (% in particle size control section)	18	12	21
pH (in particle size control section)	6.1	6.0	6.2
Available water capacity (mm/m)	22	9	31
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	1	5
Exposed bedrock	7	0	20
Gravel	27	15	40
Cobble	6	3	10
Stones	4	1	10
Boulders	1	0	3
Litter	10	5	20
Wood	0	0	0
Moss and lichen	5	3	6
Basal vegetation	37	20	45
Water	0	0	0

Table 103—Constancy/cover table for common plant species occurring in the ARTRV2/FEID, Ledgefork Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARFR4	*Artemisia frigida*	fringed sagewort	67	2	1	3
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	25	10	35
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	100	1	1	1
Forbs:						
AGGL	*Agoseris glauca*	pale agoseris	67	1	1	1
ALCE2	*Allium cernuum*	nodding onion	100	1	1	1
ANUM	*Antennaria umbrinella*	umber pussy-toes	67	1	1	1
ASMI9	*Astragalus miser*	timber milkvetch	100	2	1	3
BAIN	*Balsamorhiza incana*	hoary balsamroot	100	1	1	1
BOEX2	*Boechera exilis*	second rockcress	67	1	1	1
CAFL7	*Castilleja flava*	yellow paintbrush	67	1	1	1
CRMO4	*Crepis modocensis*	low hawksbeard	100	2	1	3
DOCO	*Dodecatheon conjugens*	slimpod shooting star	67	1	1	1
ERCA2	*Erigeron caespitosus*	tufted fleabane	67	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	67	1	1	1
EROV	*Eriogonum ovalifolium*	cushion buckwheat	100	1	1	1
LERE7	*Lewisia rediviva*	bitterroot	100	1	1	1
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	67	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	100	1	1	1
OXSE	*Oxytropis sericea*	white locoweed	67	2	1	3
PHHO	*Phlox hoodii*	Hood’s phlox	100	2	1	3
PHMU3	*Phlox multiflora*	many-flowered phlox	67	2	1	3
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	67	2	1	3
STAC	*Stenotus acaulis*	stemless mock goldenweed	67	2	1	3
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	5	1	10
FEID	*Festuca idahoensis*	Idaho fescue	100	8	5	10
POSE	*Poa secunda*	Sandberg bluegrass	100	22	15	30
Graminoids:						
CACA13	*Carex capitata*	capitate sedge	67	1	1	1

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Mountain Big Sagebrush/Bluebunch Wheatgrass, Winspect Family Ecological Type

Artemisia tridentata var. *vaseyana*/*Elymus spicatus*, Winspect Family Ecological Type

ARTRV2/ELSP3, Winspect Family ET

N = 10

Distribution

The mountain big sagebrush/bluebunch wheatgrass, Winspect Family Ecological Type occurs in the study area within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map units 12L, 15L, and 351L.

Environment

Aspect: South [1], southeast [2], south-southeast [4], south-southwest [3].

Landforms and Landscape Position: Backslopes.

Parent Materials: Colluvium. Colluvium over residuum. Colluvium over granitic glacial till.

In map unit 12L and 15L, parent materials are mixed Bighorn Dolomite and Madison/Gallatin Limestone colluvium. The colluvium is generally deep enough that residuum is not observed within 100 cm of the soil surface. On occasion, the colluvium is only a thin veneer (<100 cm) and residuum is present closer to the soil surface. In those instances, parent materials are mixed limestone and dolomite colluvium over limestone or shale/siltstone residuum in map units 12L and 15L, respectively. In map unit 351L, parent materials are mixed dolomite and limestone colluvium over granitic glacial till.

Bedrock: Cambrian Gros Ventre Shale, Cambrian Gallatin Limestone, Mississippian Madison Limestone, late Mississippian/early Pennsylvanian Amsden Siltstone.

In map unit 12L, bedrock is either Madison or Gallatin Limestone, or Bighorn Dolomite. In map unit 15L, bedrock is Gros Ventre Shale or Amsden Siltstone. In map unit 351L, bedrock is either Gros Ventre Shale or Flathead Sandstone.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation is 43 to 63 cm.

Additional environment data summaries are provided in Table 104.

Potential natural vegetation

The potential natural vegetation of this ecological type is the mountain big sagebrush/bluebunch wheatgrass habitat type antelope bitterbrush phase. Mountain big sagebrush and antelope bitterbrush form a dense, moderately tall shrub layer, typically less than 1 m tall. Utah juniper co-dominates with mountain big sagebrush at sites lower than approximately 2,300 m. Yellow rabbitbrush and Utah snowberry are other common shrubs that may be present at high abundance especially at lower elevation sites. The herbaceous layer is dominated by bluebunch wheatgrass, Sandberg bluegrass, and spike fescue. Cheatgrass is common and may occur in high amounts at recently burned sites. Common herbaceous species include pale agoseris, hoary balsamroot, turpentine wavewing, sulphur-flower buckwheat, northern Idaho biscuitroot, oblongleaf bluebells, Hood's and many-flowered phlox, and woolly groundsel. Species proliferated by fire include pale madwort, white sagebrush, sanddune wallflower, and western gromwell. Table 105 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the ARTRV2/ELSP3, Winspect Family ET were deep and calcareous with a low to moderate degree of soil development, moderate to high coarse fragments (39-86%, avg. 55%), and variable clay (10–30%, avg. 17%). Accumulations of clay minerals were the result of in situ weathering rather than pedogenic transport to subsurface horizons. A typical soil featured an A/Bk horizonation. Mollisols featured a mollic epipedon (avg. 31 cm thick), while Inceptisols featured a thin ochric epipedon (avg. 12 cm thick). Diagnostic subsurface horizons included a thick calcic horizon (avg. 60 cm thick). One soil in Sinks Canyon was formed from mixed limestone and dolomite colluvium over granitic glacial till, and featured a sandy (94%) C-horizon (26+ cm thick) below a calcic horizon. Another soil in Sinks Canyon was formed from mixed limestone and dolomite colluvium over Dry Creek Shale (Gallatin Form.) residuum. This soil featured a massive, very gravelly, clay-rich (30%) C-horizon (30+ cm thick) below a calcic horizon. Lastly, one soil was formed from mixed dolomite and limestone colluvium over Gros Ventre Shale residuum. This soil featured a distinct color difference between parent materials, ranging from dark grayish brown to very dark grayish brown to pale brown (10YR 3/2-4/2-6/3; dry) in the mixed colluvium to greenish brown-yellowish (2.5Y 7/3-8/2; dry) in the shale residuum. Particle size class was loamy-skeletal. The soils were Typic Calciustolls [7], Pachic Calciustolls [1], and Typic Calciustepts [2].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Typic Calciustolls

A1—0 to 10 cm: brown (10YR 4/3) very gravelly loam, very dark grayish brown (10YR 3/2), moist; 47% sand; 15% clay; weak very fine granular structure; very friable, soft, slightly sticky, nonplastic; common fine roots and many very fine roots; common fine and common very fine pores; 41% 2- to 75-mm unspecified fragments; very slight effervescence, by Hcl, 1 normal; moderately alkaline, pH 7.9; clear wavy boundary.

A2—10 to 27 cm: brown (10YR 4/3) medium gravelly loam, very dark grayish brown (10YR 3/2), moist; 49% sand; 16% clay; weak fine subangular blocky structure; very friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common very fine roots;common fine and common very fine pores; 1% fine carbonate nodules in matrix; 22% 2- to 75-mm unspecified fragments; slight effervescence, by HCl, 1 normal; slightly alkaline, pH 7.6; clear wavy boundary.

Bk1—27 to 43 cm: pale brown (10YR 6/3) fine gravelly loam, dark brown (10YR 3/3), moist; 45% sand; 18% clay; weak fine subangular blocky structure, and moderate fine granular structure; very friable, soft, slightly sticky, moderately plastic; common fine roots and common coarse roots and common very fine roots; common fine and common coarse and common very fine pores; patchy faint carbonate coats on rock fragments; 1% fine carbonate nodules in matrix; 29% 2- to 75-mm unspecified fragments; strong effervescence, by HCl, 1 normal; moderately alkaline, pH 8.2; clear smooth boundary.

Bk2—43 to 74 cm: very pale brown (10YR 7/3) very gravelly sandy loam, brown (10YR 5/3), moist; 57% sand; 13% clay; moderate coarse subangular blocky structure parting to moderate medium subangular blocky structure; very friable, soft, slightly sticky, slightly plastic; common fine roots and common coarse roots and common very fine roots; common fine and common coarse and common very fine pores; 10% fine distinct carbonate nodules in matrix and 1% fine threadlike carbonate masses in matrix; 8% 76- to 250-mm unspecified fragments and 50% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.2; clear smooth boundary.

Bk3—74 to 102 cm: very pale brown (10YR 7/3) extremely gravelly loam, pale yellow (2.5Y 7/3), moist; 51% sand; 12% clay; moderate coarse subangular blocky structure parting to moderate medium subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common very fine roots; common fine and common very fine pores; 25% patchy carbonate coats on rock fragments; 10% fine distinct carbonate nodules in matrix; 62% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.2; abrupt smooth boundary.

Bk4—102 to 107 cm: light gray (10YR 7/2) very gravelly loam, olive brown (2.5Y 4/4), moist; 45% sand; 22% clay; moderate fine subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; common fine roots and common very fine roots; common fine and common very fine pores; patchy distinct carbonate coats on rock fragments; 10% medium distinct carbonate nodules in matrix; 45% 2- to 75-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.2.

Ecology

The mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET occurs on Gros Ventre and Amsden backslopes in mixed limestone and dolomite colluvium over shale or siltstone residuum. This ET is located between the ARTRV2/FEID, Shawmut Family ET on footslope positions and the ARTRR4/ELSP3, Winspect Family ET on upper backslopes and shoulders. The environment in the mountain big sagebrush/bluebunch wheatgrass, Winspect Family ET is intermediate between the two adjacent types, being more exposed and drier than the footslope positions and less exposed and more mesic than the upper backslope and shoulder positions. The soils, which are derived from coarser-grained more resistant limestone and dolomite, typically have less clay, higher rock fragments, and lower available water-holding capacity than those derived from shale and siltstone in the ARTRV2/FEID, Shawmut Family ET. The intermediate environment is suitable for bluebunch wheatgrass, which is more drought tolerant than Idaho fescue but is also more sheltered, allowing for mountain big sagebrush, a less drought tolerant species than Wyoming three-tip sagebrush.

Management considerations

The ARTRV2/ELSP3, Winspect Family ET provides excellent foraging opportunities for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Bluebunch wheatgrass is moderately tolerant of grazing and is considered a grazing decreaser since heavy grazing can result in lower root and stem carbohydrate reserves, a condition leading to decreased vigor or mortality. Bluebunch wheatgrass is most sensitive to grazing during its active growth period in spring and early summer (Zlatnik 1999b). Antelope bitterbrush is a highly palatable, nutrient- and protein-rich browse species utilized by a variety of wild and domestic ungulates (Zlatnik 1999a). Antelope bitterbrush is moderately browse tolerant and is considered a decreaser under heavy browsing pressure.

The productive nature of these communities, combined with fire suppression, has resulted in an abundance of fuels in this Ecological Type. Invasive plants, including cheatgrass and musk thistle, tend to be associated with fire in this ET. Fires in the ARTRV2/ELSP3, Winspect Family ET are expected to be severe. Land managers should proceed with caution when considering a prescribed burn in the ARTRV2/ELSP3, Winspect Family ET. Invasive plant surveys should be conducted prior to any prescribed burn in order to reduce the risk of spreading invasive plants, which often thrive following fire. Also, thinning and physical removal (of thinned material) of mountain big sagebrush and Utah juniper prior to prescribed burns may help reduce fire severity, thus increasing the success of mountain big sagebrush, bluebunch wheatgrass, and antelope bitterbrush regeneration.

Mountain big sagebrush is killed by even light severity fires and will not resprout from the root crown if the above ground portion of the plant is completely killed (Welch 2005). Antelope bitterbrush is highly susceptible to fire kill and is often killed by summer or fall fire (Zlatnik 1999a). Antelope bitterbrush in some regions may sprout after light severity spring fire; however, the resprouting ability of antelope bitterbrush is dependent on a number of factors, including fire severity, season, plant genetics, carbohydrate stores, and age. Fire generally favors bluebunch wheatgrass and stimulates flowering, seed, and tiller production (Zlatnik 1999b). Seasonality of fires strongly affects mortality. Bluebunch wheatgrass receives the least damage when burned while dormant in fall, winter, or early spring and the most damage when burned while actively growing in the late spring and summer. Soil moisture status prior to and following fires also affects mortality and recovery time. Recovery following fires is generally rapid (one-five years); however, a lack of adequate soil moisture following a burn can slow recovery and increase mortality. Low soil moisture prior to burning increases fire severity.

Lastly, in map unit 15L, where this ET is underlain by Gros Ventre Shale or Amsden Siltstone bedrock, landslide potential is high, especially following a wetter than normal winter/spring on steep (approximately >35%), recently burned slopes.

Similar ecological types

Ecological Type 1

Type: Mountain big sagebrush/Idaho fescue, Kiev Family ET

Floristic differences: The two types differ floristically in that the PNV of the Kiev Family ET is the mountain big sagebrush/Idaho fescue habitat type, while the PNV of the Winspect Family ET is the mountain big sagebrush/ bluebunch wheatgrass habitat type.

Environmental differences: The two types differ environmentally in that the Kiev Family ET occurs on footslopes, while the Winspect Family occurs on backslopes.

Ecological Type 2

Type: Mountain big sagebrush/Idaho fescue, Shawmut Family ET

Floristic differences: The two types differ floristically in that the PNV of the Shawmut Family ET is the mountain big sagebrush/Idaho fescue habitat type, while the PNV of the Winspect Family ET is the mountain big sagebrush/ bluebunch wheatgrass habitat type.

Environmental differences: The two types differ environmentally in that the Shawmut Family ET occurs on footslopes, while the Winspect Family occurs on backslopes.

Table 104—Summary of environmental variables for the ARTRV2/ELSP3, Winspect Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,350	2,113	2,629
Slope (%)	27	15	42
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	525	431	627
Degree days	19,440	16,310	22,520
Frost-free days	21.2	19.6	22.5
Site water balance (mm/year)	-423	-546	-322
Average annual temperature (°C)	3.0	1.8	4.2
Total annual potential evapotranspiration (mm)	759	675	834
Summer radiation (KJ)	20,760	19,930	20,960
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	55	39	86
Clay (% in particle size control section)	17	10	30
pH (in particle size control section)	8.1	7.9	8.3
Available water capacity (mm/m)	64	30	93
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	12	1	20
Exposed bedrock	1	0	5
Gravel	11	1	40
Cobble	4	0	10
Stones	4	1	10
Boulders	5	0	15
Litter	16	3	40
Wood	2	0	5
Moss and lichen	1	0	2
Basal vegetation	49	20	70
Water	0	0	0

Table 105—Constancy/cover table for common plant species occurring in the ARTRV2/ELSP3, Winspect Family ET.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Shrubs:						
ARTRR4	*Artemisia tripartita*	Wyoming three-tip sagebrush	60	3	1	5
ARTRV2	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	28	3	40
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	60	2	1	5
JUOS	*Juniperus osteospema*	Utah juniper	40	10	1	20
PUTR2	*Purshia tridentata*	antelope bitter-brush	90	16	1	30
ROWO	*Rosa woodsii*	woods rose	50	2	1	3
SYORU	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry	50	4	1	10
Forbs:						
AGGL	*Agoseris glauca*	pale agoseris	70	1	1	1
ALAL3	*Alyssum alyssoides*	pale madwort	40	2	1	5
ARLU	*Artemisia ludoviciana*	white sagebrush	40	2	1	3
ASAUG	*Astragalus australis* var. *glabriusculus*	Indian milkvetch	40	2	1	3
ASMI9	*Astragalus miser*	timber milkvetch	40	2	1	5
BAIN	*Balsamorhiza incana*	hoary balsamroot	50	4	1	10
COPA3	*Collinsia parviflora*	small-flowered blue-eyed mary	60	1	1	1
CRAC2	*Crepis acuminata*	tapertip hawksbeard	40	2	1	3
CYTEA	*Cymopterus terebinthinus* var. *albiflorus*	turpentine wavewing	40	6	3	15
ERAS2	*Erysimum asperum*	sanddune wallflower	40	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	40	1	1	1
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	50	2	1	3
LILE3	*Linum lewisii*	prairie flax	50	1	1	1
LIRU4	*Lithospermum ruderale*	western gromwell	50	1	1	3
LOOR	*Lomatium orientale*	Northern Idaho biscuitroot	70	1	1	1
MEVI4	*Mertensia viridis*	oblongleaf bluebells	60	2	1	3
PACA15	*Packera cana*	woolly groundsel	60	1	1	1
PEHU	*Penstemon humilis*	low beardtongue	40	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	90	2	1	5
PHMU3	*Phlox multiflora*	many-flowered phlox	40	2	1	3
TAOF	*Taraxacum officinale*	common dandelion	40	1	1	1
Grasses:						
BRTE	*Bromus tectorum*	cheatgrass	50	14	1	40
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	10	3	20
KOMA	*Koeleria macrantha*	prairie junegrass	60	4	1	10
LEKI2	*Leucopoa kingii*	spike-fescue	70	3	1	10
POSE	*Poa secunda*	Sandberg bluegrass	90	16	1	40
Graminoids:						
CARO5	*Carex rossii*	Ross' sedge	40	5	1	10

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Miscellaneous Mountain Big Sagebrush Types

Mountain Big Sagebrush/Idaho Fescue, Kiev Family Ecological Type

Artemisia tridentata var. *vaseyana/ Festuca idahoensis*, Kiev Family ET

ARTRV2/FEID, Kiev Family ET

N = 2

The mountain big sagebrush/Idaho fescue, Kiev Family Ecological Type occurs along the eastern flank of the WRR within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). This ET occurs on moderate to low gradient (avg. 21%) footslopes on the Gros Ventre and Amsden Formations. It is a component of map unit 15L. Parent materials were mixed limestone and dolomite colluvium over shale residuum. Soils had low coarse fragments (avg. 24%), relatively moderate clay (avg. 18%), and high available water-holding capacity (avg. 116 mm/m). Soils were deep, fine-loamy Typic Calciustolls.

Potential natural vegetation of this ET is the mountain big sagebrush/Idaho fescue habitat type (Tweit and Houston 1980). Mountain big sagebrush forms a thicket shrub cover and is sometimes joined by yellow rabbitbrush and antelope bitterbrush. Forbs are especially species rich. Common species include western yarrow, timber milkvetch, pale agoseris, sulphur-flower buckwheat, spotted fritillary, northern Idaho biscuitroot, white locoweed, Hood's and many-flowered phlox, and lambstongue ragwort. Idaho fescue always occurs at moderately high abundance (avg. 18%) and is commonly joined by bluebunch wheatgrass, spike fescue, and Sandberg bluegrass.

The ARTRV2/FEID, Kiev Family ET differs from the ARTRV2/FEID, Shawmut Family ET in that the former features fine-loamy particle size and little to no subsurface clay accumulations, while the latter features loamy-skeletal particle size and strong illuviation of clay into subsurface horizons.

Mountain Big Sagebrush/Idaho Fescue, Corbly 351L Family Ecological Type

Artemisia tridentata var. *vaseyana/Festuca idahoensis*, Corbly 351L Family Ecological Type

ARTRV2/FEID, Corbly 351L Family ET

N = 1

The mountain big sagebrush/Idaho fescue, Corbly 351L Family Ecological Type occurs within the Granitic Subalpine Zone ecoregion of Chapman and others (2004). This ET occurs on south-facing, rolling granitic glacial till deposits of Pinedale age (Dahms 2004b) along the upper extent of the Sinks Canyon moraine in the Middle Fork Popo Agie River drainage. It is a component of map unit 351L. Soils were high in coarse fragments (79%) and low in clay (avg. 4%). Soils were sandy-skeletal, Entic Haplustolls.

Potential natural vegetation of this ET is the mountain big sagebrush/Idaho fescue habitat type (Tweit and Houston 1980). Mountain big sagebrush, often joined by antelope bitterbrush, is reduced in stature due to the extremely rocky soils. Common juniper and Utah snowberry occur at low abundance throughout the community. Idaho fescue and Sandberg bluegrass are the predominant herbaceous species. Common forbs and graminoids occurring at low abundance include hoary and arrowleaf balsamroot, sulphur-flower buckwheat, red avens, bluebunch wheatgrass, and Columbia needlegrass. Cushion plants and succulents, including lance-leaved stonecrop, ballhead sandwort, bitterroot, umber pussy-toes, and many-flowered phlox, commonly occur and are indicative of the droughty conditions experienced at these sites.

The ARTRV2/FEID, Corbly 351L Family ET provides important foraging grounds for domestic and wild ungulates. Bedding opportunities and thermal and hiding cover are close at hand due to the proximity of this ET to adjacent forested stands. Although the forage production of the ET is lower than other sagebrush types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer.

The ARTRV2/FEID, Corbly 351L Family ET differ environmentally from the ARTRV2/FEID, Corbly 166D Family ET in that the Corbly 166D Family ET occurs in the South Pass Granite-Greenstone belt and features soils formed from metasedimentary and metamorphic residuum, while the Corbly 351L Family ET occurs in upper section of Sinks Canyon and features soils formed from granitic glacial till.

Upland Grassland Series

Idaho Fescue Series

Principal Species Descriptions

Idaho fescue

Festuca idahoensis Elmer

Idaho fescue occurs throughout the Rocky Mountain and Pacific States from eastern British Columbia and Alberta, south to Arizona, New Mexico, and western Texas (USDA NRCS 2007b; Zouhar 2000). To the east of the Rocky Mountains, Idaho fescue is a minor component of plains grasslands and occurs in the high plains of eastern Montana, Wyoming, and Colorado, western South Dakota, and Saskatchewan.

Idaho fescue is a common bunchgrass found in sagebrush, grassland, woodlands, and dry-forest communities, occurring across a broad altitudinal gradient from 300 m in Oregon to 4,000 m in Colorado (Zouhar 2000). Idaho fescue occurs at elevations between 300 and 2,460 m in Oregon and Washington, 400 and 2100 m in Idaho, and 1,500 and 2,400 m in Montana. On the east slope of the WRR in Wyoming, Idaho fescue occurs between roughly 1,700 and 3,600 m (Massatti 2007). Mean annual precipitation in Idaho fescue communities is typically greater than 380 mm but may be as low as 186 mm. In the northern portion of its geographic range, Idaho fescue inhabits the drier end of the moisture spectrum, while further south it shifts to more mesic sites at higher elevations and on north-facing slopes. Similarly, at higher elevations, Idaho fescue generally inhabits more xeric sites, while at lower elevations, it is limited to more mesic sites, including north-facing slopes, moist microsites, or soils with higher water holding capacity.

Idaho fescue occurs on soil derived from all major rock types, including sedimentary, igneous, and metamorphic (Svalberg and others 1997). Moisture availability tends to be more important than soil parent material in determining the distribution of Idaho fescue (Zouhar 2000). However, soil parent material influences soil texture, which is an important factor influencing AWC of soils. Hironaka and others (1983), working in sagebrush/Idaho fescue communities in Idaho, stated that soil texture interacts with soil moisture, slope exposure (i.e., solar radiation), and/or nutrients to affect the distribution of Idaho fescue. For instance, in mountain big sagebrush communities in the 300–350 mm precipitation zone located on fine- to medium-textured soils, Idaho fescue was present on all slope aspects. However, Idaho fescue was absent on south-facing slopes in mountain big sagebrush communities located within the same precipitation zone on coarse-textured soils. Idaho fescue is intolerant of permanent soil saturation but is found in riparian areas in soils that are temporarily saturated early in the growing season and well drained the remainder of the year. Deep snow accumulation may also negatively affect Idaho fescue abundance in subalpine and alpine meadows (Zouhar 2000).

Idaho fescue is a native, cool-season, perennial, strongly caespitose bunchgrass with culms standing 30 to 100 cm high (Zouhar 2000). Idaho fescue reproduces from tillers and seeds. Reproductive success by seed is highly variable and dependent on proper environmental conditions, including an after-ripening period of six months, followed by adequate soil moisture. Tillers arise from a small budding zone within the root crown area. Idaho fescue is most productive in full sunlight conditions but is also tolerant of partial shade.

Idaho fescue is tolerant of low severity, rapid fires while moderate to high severity and long-lasting fires can destroy the root crown (Zouhar 2000). Idaho fescue receives the least damage when burned while dormant in fall, winter, or early spring and the most damage when burned while actively growing in the late spring and summer. Season of burn, as it affects soil moisture status prior to and following fires, is an important factor affecting mortality and recovery time. Low severity burns during periods of adequate soil moisture stimulate rapid tillering and seedling establishment with the onset of fall moisture. However, moderate to high severity burns will destroy after-ripened seeds stored in the soil from the previous summer. A lack of adequate soil moisture before and after a fire can increase fire severity, slow recovery, and increase mortality. Fire suppression can lead to an accumulation of fine fuels surrounding the root crown, and an increase in fire severity.

The species associated with Idaho fescue can affect the fire return interval and severity of fires, which in turn influences the morality and recovery rates of Idaho fescue. Fire return intervals range from 3 to 40 years in bluebunch wheatgrass-Idaho fescue grasslands, 20 to 70 years in big sagebrush steppe, and 25 to 100 years in Rocky Mountain Douglas-fir communities. Plant communities with high amounts of shrub cover can result in increased burn duration and temperature. In contrast, nearly pure stands of Idaho fescue typically have lower fuel loads, which result in shorter duration of moderate to low severity burns. Idaho fescue communities are susceptible to invasion by annual grasses such as cheatgrass, which can shorten fire return intervals (<10 years), increase fire intensity, and permanently change the fire regime at the expense of Idaho fescue.

Prescribed burns may be used in the management of Idaho fescue communities. However, managers should proceed with caution as guidelines for controlled burns are highly dependent on the species associated with Idaho fescue, time since last burn, site conditions (elevation, aspect, slope), soil moisture status, seasonality, and pre- and post-fire management activities. For more detailed guidelines, see the “Management Considerations” section of the Ecological Types that feature Idaho fescue as an important component of the plant community.

Idaho fescue is a highly preferred forage species of wild and domestic ungulates (Zouhar 2000). Protein content is typically highest in the spring and decreases throughout the growing season. Light to moderate grazing can enhance Idaho fescue grasslands. However, Idaho fescue is only moderately tolerant of grazing and is considered a grazing decreaser under heavy grazing. The degree of grazing pressure that Idaho fescue can sustain depends on the interactions among wildlife and livestock using the range, plant phenology, type of grazing system used, competition from associated vegetation, plant vigor, and site conditions. Heavy grazing reduces the ability of Idaho fescue to compete with non-native species, including spotted knapweed. Idaho fescue may be a good choice for rehabilitation of disturbed sites, although establishment can be slow. Zouhar (2000) provided an in-depth review of Idaho fescue in rehabilitating disturbed sites.

Idaho Fescue-Bluebunch Wheatgrass-Columbia Needlegrass, Elwood Family Ecological Type

Festuca idahoensis-Elymus spicatus-Achnatherum nelsonii, Elwood Family Ecological Type

FEID-ELSP3-ACNE9, Elwood Family ET

N = 3

Distribution

The Idaho fescue-bluebunch wheatgrass-Columbia needlegrass, Elwood Family Ecological Type occurs in the southern study area within the granitic subalpine zone of Chapman and others (2004). This ET occurs in an area of park-forest vegetation (Lynch 1998) north and east of Fiddlers Lake around Blue Ridge, the headwaters of Sawmill and Hidden Creek, and near Dickinson Park. It is a component of map unit 309A and 306L.

Environment

Aspect: South [1], south-southwest [1], southwest [1].

Landforms and Landscape Position: Mountain slopes. Summits, shoulders, backslopes, footslopes, toeslopes.

Parent Materials: Colluvium, alluvium, residuum.

On shoulders and summits, parent materials are residuum.

On footslopes and toeslopes, parent materials are colluvium or alluvium, respectively.

Bedrock: Granodiorite of the Louis Lake Pluton, porphyritic quartz monzonite. In the area north and east of Fiddlers Lake, bedrock is granodiorite. In the area around Dickinson Park, bedrock is porphyritic quartz monzonite.

Climate: Cryic temperature regime and Udic moisture regime. Estimated annual precipitation ranges from 70 to 72 cm.

Additional environment data summaries are provided in Table 106.

Potential natural vegetation

On summits, shoulders, and upper backslopes, the potential natural vegetation of this ET is the Idaho fescue-bluebunch wheatgrass-Columbia needlegrass habitat type. This habitat is similar to the *Festuca idahoensis-Agropyron spicatum-Stipa occidentalis* habitat type of Tweit and Houston (1980). On lower backslopes, footslopes, and toeslopes, the potential natural vegetation of this ET is the Idaho fescue-red avens plant community type (Johnson 2004). In each of the above vegetation types, Idaho fescue is the dominant grass species.

The Idaho fescue-bluebunch wheatgrass-Columbia needlegrass habitat type represents the drier end of the Idaho fescue series. Mountain big sagebrush and common juniper regularly occur as scattered, stunted individuals. Bluebunch wheatgrass and spike fescue co-dominate with Idaho fescue. Columbia needlegrass and Sandberg and Wheeler's bluegrass are always present at low amounts. The soil surface is generally bouldery with large patches of exposed sands and gravels. Forbs are sparse and generally occur in small clusters dispersed across the landscape. The cushion plants many-flowered phlox, sulphur-flower buckwheat, ballhead sandwort, and umber pussy-toes are the most common and abundant forbs. Bitterroot, with its thick, fleshy taproot, is especially adapted to survive at these drought-stricken sites. Other common forbs include western yarrow, pale agoseris, timber milkvetch, cutleaf daisy, and oblongleaf bluebells.

The Idaho fescue-red avens plant community type represents the moist end of the Idaho fescue series. Sandberg bluegrass shares dominance with Idaho fescue, and Columbia needlegrass is never present. Similar to the Idaho fescue-red avens plant community type first described by Johnson (2004) for northeastern Oregon, buckwheat and goldenweed co-occur with red avens. In the WRR, sulphur-flower and cushion buckwheat and many-stemmed goldenweed replace the golden and creamy buckwheat and woolly goldenweed reported by Johnson (2004) for the northeastern Oregon type, respectively. Other common forbs include timber milkvetch, ballhead sandwort, umber pussy-toes, and Wyoming kittentail. Poverty oatgrass may also occur in low abundance. Table 107 provides a summary of species constancy and cover for this ecological type.

Soils

On backslopes, footslopes, and toeslopes, soils in the FEID, Elwood Family ET were moderately deep with a high degree of soil development, high rock fragments (avg. 72%), moderate clay (avg. 19%), and dark brown in upper soil horizons. Soils typically feature an A/Bt/R horizonation. Diagnostic soil horizons include a mollic epipedon (avg. 31 cm thick), a thick argillic horizon (avg. 47 cm

thick), and lithic contact (avg. 89 cm depth). Soils were loamy-skeletal, Typic Argicryolls.

On shoulders and summits, soils were shallow with a low degree of development, high rock fragments (>70%), and low clay (<12%). Particle size class was sandy-skeletal. Soils typically feature an A/Bw/Cr-R horizonation. Diagnostic soil horizons include an ochric epipedon (22 cm thick), and shallow to moderately deep paralithic or lithic contact (<100 cm depth). Soils were sandy-skeletal Typic Cryorthents.

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, Typic Argicryolls

A—0 to 34 cm: very dark brown (10YR 2/2) very gravelly coarse sandy loam, brown (10YR 4/3), dry; 62% sand; 16% clay; moderate coarse subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common medium and many very fine pores; 3% 76- to 250-mm unspecified fragments and 33% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.3; abrupt smooth boundary.

Bt1—34 to 62 cm: strong brown (7.5YR 4/6) very gravelly sandy clay loam, strong brown (7.5YR 5/6), dry; 65% sand; 20% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 3% faint clay films on surfaces along pores; 4% 76- to 250-mm unspecified fragments and 38% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.4; gradual wavy boundary.

Bt2—62 to 76 cm: yellowish brown (10YR 5/4) extremely bouldery sandy clay loam, very pale brown (10YR 7/4), dry; 43% sand; 22% clay; weak fine subangular blocky structure, and moderate fine granular structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; distinct clay films on surfaces along pores and 28% distinct clay films on all faces of peds; 39% 601- to 3000-mm unspecified fragments and 44% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.3; clear wavy boundary 2Bt3—76 to 93 cm: yellowish brown (10YR 5/4) extremely bouldery sandy clay loam, light yellowish brown (10YR 6/4), dry; 68% sand; 23% clay; moderate fine subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; prominent clay films on all faces of peds and 60% prominent clay films on all faces of peds; 40% 2- to 75-mm unspecified fragments and 43% 601- to 3000-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.1; abrupt wavy boundary.

2R—93 to 118 cm: granodiorite bedrock.

Management considerations

The FEID-ELSP3-ACNE9, Elwood Family ET provides important foraging grounds for wild and domestic ungulates, while adjacent forest patches (PIAL/CARO5, Como Family ET) provide close proximity to hiding and thermal cover. Grizzly bears may also forage on bulbs and tubers in these forest openings in the spring and early summer. Forage production is highest in the Idaho fescue-red avens plant community type. This ET also has high aesthetic value. Hikers, hunters, mountain bikers, and wranglers traveling through these forest openings will appreciate the open views of the surrounding high country, while adjacent forest patches provide an opportunity for shade and shelter from wind among the ancient whitebark pine. Historically, light ground fires sparked by lighting strikes were probably quite common in this ET. Low severity prescribed fire can be used to reduce fuel loadings and maintain the park-forest mosaic.

Similar ecological types

Ecological Type 1

Type: None

Table 106—Summary of environmental variables for the FEID-ELSP3-ACNE9, Elwood Family ET.

General Environment	**Average**	**Min**	**Max**
Elevation (m)	2,909	2,898	2,918
Slope (%)	20	9	38
Climate	**Average**	**Min**	**Max**
Average annual precipitation (mm)	711	702	716
Degree days	13,520	13,350	13,780
Frost-free days	18.3	18.2	18.4
Site water balance (mm/year)	-264	-282	-237
Average annual temperature (°C)	0.6	0.5	0.7
Total annual potential evapotranspiration (mm)	543	540	546
Summer radiation (KJ)	20,540	20,050	2,0800
Soils	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	77	59	88
Clay (% in particle size control section)	16	10	21
pH (in particle size control section)	5.1	4.9	5.3
Available water capacity (mm/m)	27	9	56
Ground Surface Components; Cover	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	13	10	20
Exposed bedrock	8	0	15
Gravel	25	10	40
Cobble	7	0	10
Stones	7	0	10
Boulders	6	3	10
Litter	8	5	15
Wood	1	0	3
Moss and lichen	4	1	10
Basal vegetation	20	15	30
Water	0	0	0

Table 107—Constancy/cover table for common plant species occurring in the FEID-ELSP3-ACNE9, Elwood Family ET.

Characteristic		**Species**		**Con**	**Cov**	**Min**	**Max**
					Percent		
Shrubs:							
ARTRV2	S	*Artemisia tridentata* var. *vaseyana*	mountain big sagebrush	100	5	5	5
JUCOD	S	*Juniperus communis* var. *depressa*	common juniper	100	2	1	3
Forbs:							
ACMIL3	F	*Achillea millefolium* var. *lanulosa*	western yarrow	100	1	1	1
AGGL	F	*Agoseris glauca*	pale agoseris	100	2	1	3
ANUM	F	*Antennaria umbrinella*	umber pussy-toes	100	4	3	5
ASMI9	F	*Astragalus miser*	timber milkvetch	100	1	1	1
ERCO24	F	*Eremogone congesta*	ballhead sandwort	100	2	1	3
ERCOD	F	*Erigeron compositus* var. *discoideus*	cutleaf daisy	100	1	1	1
ERUM	F	*Eriogonum umbellatum*	sulphur-flower buckwheat	100	4	3	5
GETR	F	*Geum triflorum*	red avens	100	1	1	1
LERE7	F	*Lewisia rediviva*	bitterroot	100	1	1	1
MEVI4	F	*Mertensia viridis*	oblongleaf bluebells	100	1	1	1
PHMU3	F	*Phlox multiflora*	many-flowered phlox	100	3	3	3
Grasses:							
ACNE9	G	*Achnatherum nelsonii*	Columbia needlegrass	100	1	1	1
FEID	G	*Festuca idahoensis*	Idaho fescue	100	12	5	20
LEKI2	G	*Leucopoa kingii*	spike-fescue	100	3	1	5
POSE	G	*Poa secunda*	Sandberg bluegrass	100	3	3	3
POWH2	G	*Poa wheeleri*	Wheeler's bluegrass	100	2	1	3

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Miscellaneous Idaho Fescue Types

Idaho Fescue-Bluebunch Wheatgrass, Ledgefork Family Ecological Type

Festuca idahoensis-Elymus spicatus, Ledgefork Family Ecological Type

FEID-ELSP3, Ledgefork Family ET

N = 1

The Idaho fescue-bluebunch wheatgrass, Ledgefork Family Ecological Type occurs within the Granitic Subalpine Zone ecoregion of Chapman and others (2004). This ET occurs on a low to moderately sloping section of lateral moraine near Dickinson Park in compacted, granitic glacial till of Bull Lake age (Pearson and others 1973). It is a component of map unit 306L. Soils were moderately deep, high in coarse fragments (71%), sandy, and low in clay (avg. 10%). Soils were sandy-skeletal, Typic Haplocryolls.

Potential natural vegetation of this ET is the Idaho fescue-bluebunch wheatgrass habitat type (Tweit and Houston 1980). Fringed sagewort appears as scattered individuals. Due to the moderately deep, dense, and rocky nature of the soils, Idaho fescue and Sandberg bluegrass are not as robust as in Idaho fescue types on deeper soils. Wind deflation is at a maximum at these sites, as evidenced by the extensive erosion pavement of gravel-sized rock fragments (20%), high cover of moss and lichen (35%), and conspicuous number of succulents and cushion plants, including Hood’s and cushion phlox, twinflower sandwort, dwarf clover, plantain goldenweed, cushion buckwheat, lance-leaved stonecrop, ballhead sandwort, alpine bitter-root, and umber pussy-toes.

The FEID-ELSP3, Ledgefork ET provides important winter range for wild ungulates. Although the forage production of the ET is lower than other grassland types along the eastern slope of the WRR, these sites are typically blown free of snow in the winter and melt off early, providing moderate levels of forage in the spring and early summer. This ET is intolerant of moderate to high levels of trampling and is best grazed lightly early in the season.

Bluebunch Wheatgrass Series

Principal Species Descriptions

Bluebunch Wheatgrass

Elymus spicatus (Pursh) Gould

Bluebunch wheatgrass occurs throughout western North America from southern Alaska and Yukon Territory, eastern British Columbia, and Alberta, south through all Rocky Mountain and Pacific states, and into Arizona and New Mexico (USDA NRCS 2007b; Zlatnik 1999b). To the east, bluebunch wheatgrass occurs in Saskatchewan, North and South Dakota, and northern Michigan.

Bluebunch wheatgrass is a common bunchgrass found in sagebrush and grassland communities with annual precipitation between 150 and 890 mm (Zlatnik 1999b). In the intermountain basins of the western United States, bluebunch wheatgrass occurs at sites typically receiving less than 432 mm of precipitation at elevations between 91 and 1,524 m. In northeastern Oregon, bluebunch wheatgrass occurs at elevations between 365 m in the depths of Hell's Canyon to 2,470 m in the Wallowa Mountains (Johnson 2004; Johnson and Simon 1987). In Wyoming, bluebunch wheatgrass occurs between 1,000 and 2,835 m (Svalberg and others 1997; Tweit and Houston 1980). On the east slope of the WRR in Wyoming, bluebunch wheatgrass occurs between roughly 1,700 and 2,900 m (Massatti 2007). In Utah, Arizona, and California, bluebunch wheatgrass occurs between 1,370 and 2,900 m, 1,373 and 2,286 m, and 800 and 1,650 m, respectively (Zlatnik 1999b). Bluebunch wheatgrass occurs on a variety of substrates, including limestone, dolomite, sandstone, siltstone, granodiorite, quartz monzonite, gneiss, andesite, basalt, gabbro, serpentinite, and peridotite (Hironaka and others 1983; Johnson 2004; Svalberg and others 1997). Soils are typically well drained, moderately deep (50–100 cm) to deep (>100 cm), and gravelly to very gravelly and medium- to coarse-textured in upper horizons, including silt loams, loams, sandy loams, and loamy sands. Bluebunch wheatgrass is intolerant of prolonged soil saturation and saline soils.

Bluebunch wheatgrass is a native, cool-season, perennial, deep-rooting (1.4–2.0 m) bunchgrass with densely tufted culms standing 30–100 cm tall (Zlatnik 1999b). Bluebunch wheatgrass is one of the most drought-resistant native bunchgrasses due to its unusually broad range of osmoregulation and its ability to go dormant during droughty periods in late summer. Reproduction is generally accomplished vegetatively via tillers. Reproduction by seed does occur; however, bluebunch wheatgrass is highly self-sterile, does not flower and produce seed every year, and has a low success rate of seedling establishment. Bluebunch wheatgrass is most productive in full sunlight conditions but is also tolerant of partial shade.

Mean fire return intervals in bluebunch wheatgrass communities are highly dependent on the associated species mix but are mostly less than 30 years (Zlatnik 1999b). Bluebunch wheatgrass buds are protected below ground or by thick organic matter at the base of the plant, making it a fire hardy species. Fire generally favors bluebunch wheatgrass and stimulates flowering, seed, and tiller production. Seasonality of fires strongly affects mortality. Bluebunch wheatgrass receives the least damage when burned while dormant in fall, winter, or early spring and the most damage when burned while actively growing in the late spring and summer. Soil moisture status prior to and following fires also affects mortality and recovery time. Recovery following fires is generally rapid (one–five years); however, a lack of adequate soil moisture following a burn can slow recovery and increase mortality. Low soil moisture prior to burning increases fire severity. Fire suppression can lead to an accumulation of fine fuels and an increase in fire severity in bluebunch wheatgrass communities. The species associated with bluebunch wheatgrass can affect the fire return interval and severity of fires, which in turn influences the mortality and recovery rates of bluebunch wheatgrass. Plant communities with high amounts of shrub cover can result in increased burn duration and temperature. In contrast, nearly pure stands of bluebunch wheatgrass typically have lower fuel loads, which result in shorter duration of moderate to low severity burns. Bluebunch wheatgrass communities are susceptible to invasion by annual grasses such as cheatgrass, which can shorten fire return intervals, increase fire intensity, and permanently change the fire regime at the expense of bluebunch wheatgrass.

Prescribed burns may be used in the management of bluebunch wheatgrass communities. However, managers should proceed with caution as guidelines for controlled burns are highly dependent on the species associated with bluebunch wheatgrass, time since last burn, site conditions (elevation, aspect, slope), soil moisture status, and seasonality. For more detailed guidelines, see the "Management Considerations" section of the Ecological Types that feature bluebunch wheatgrass as an important component of the plant community.

Bluebunch wheatgrass is incredibly important as a forage species for wild and domestic ungulates (Zlatnik 1999b). Bluebunch wheatgrass communities provide important winter range for elk, deer, and pronghorn. Bluebunch wheatgrass is moderately tolerant of grazing and is considered a grazing "decreaser" since heavy grazing can result in lower root and stem carbohydrate reserves, a condition leading to decreased vigor or mortality. Bluebunch wheatgrass is most sensitive to grazing during its active growth period in spring and early summer. Bluebunch wheatgrass is highly effective at reducing soil erosion on the steep slopes often associated with this species. However, due to the difficulty in collecting seeds, inconsistency in seed set, and low success rate of seedling establishment, it is not recommended for use in rehabilitating disturbed sites. Lastly, at disturbed sites, bluebunch wheatgrass communities are especially susceptible to invasion by introduced and invasive species, including diffuse (*Centaurea diffusa*) and spotted knapweed (*C. maculosa*), crested (*Agropyron cristatum*) and desert wheatgrass (*A. desertorum*), leafy spurge (*Euphorbia esula*), and medusahead (*Taeniatherum caput-medusae*).

Bluebunch Wheatgrass-Sandberg Bluegrass-Mock Goldenweed—Scabland, Paunsaugunt Family Ecological Type

Elymus spicatus-Poa secunda-Stenotus—Scabland, Paunsaugunt Family Ecological Type

ELSP3-POSE-STENO7 Scabland, Paunsaugunt Family ET

N = 3

Distribution

The bluebunch wheatgrass-Sandberg bluegrass-mock goldenweed scabland, Paunsaugunt Family Ecological Type occurs in the study area within the dry mid-elevation sedimentary mountains ecoregion of Chapman and others (2004). In the northern study area, this ecological type occurs from Little Warm Spring Creek in the northwest to Red Creek in the southeast. In the southern study area, this ecological type occurs from just northeast of Dickinson Park southeast to Limestone Mountain. It is a component of map unit 12L.

Environment

Aspect: East-northeast [1], northeast [1], south-southwest [1].

Landforms and Landscape Position: Summits and shoulders.

Parent Materials: Residuum.

Bedrock: Cambrian Gallatin Limestone, Mississippian Madison Limestone.

Climate: Frigid temperature regime and Ustic moisture regime. Estimated annual precipitation was 56 and 67 cm.

Additional environment data summaries are provided in Table 108.

Potential natural vegetation

The potential natural vegetation of this ecological type is bluebunch wheatgrass-Sandberg bluegrass-mock goldenweed scabland habitat type. This habitat type is similar in concept to the bluebunch wheatgrass-Sandberg's bluegrass scabland plant community type classified for northeastern Oregon by Johnson and Simon (1987). Bluebunch wheatgrass, Sandberg bluegrass, and prairie Junegrass form a disjunct grass cover growing in patches of deeper soil between bands of limestone flagstones and exposed bedrock. Cushion plants dominate the forb layer of this habitat type. Clusters of stemless or narrowleaf mock goldenweeds, Hood's and many-flowered phlox, and lance-leaved stonecrop occur growing in the interstices between flagstones. Other common herbaceous species include timber milkvetch, oblongleaf bluebells, Cous biscuit-root, Wyoming kittentails, and diamondleaf saxifrage. Spike sedge is a low growing, densely tufted sedge that often occurs in this type. Table 109 provides a summary of species constancy and cover for this ecological type.

Soils

Soils in the ELSP3-POSE-STENO7 Scabland, Paunsaugunt Family ET were shallow and moderately deep and carbonate rich with a low to moderate degree of soil development, high coarse fragments (avg. 72%), low to moderate clay (5–21%, avg. 14%), and a relatively thick mollic epipedon (avg. 25 cm thick). A typical soil features an A/R horizonation. Diagnostic soil horizons include a mollic epipedon, and shallow to moderately deep lithic contact (avg. 34 cm depth). One soil was moderately deep (58 cm), and featured a 44-cm thick calcic horizon, and an extremely stony (60-90% flagstones) 28-cm thick argillic horizon directly above bedrock. Particle size class was loamy-skeletal. Soils were Typic Calciustolls [1] and Lithic Haplustolls [2].

Typical pedon description

Soil Classification: Loamy-skeletal, mixed, superactive, frigid Lithic Haplustolls

A1—0 to 12 cm: dark grayish brown (10YR 4/2) extremely gravelly fine sandy loam, very dark grayish brown (10YR 3/2), moist; 64% sand; 15% clay; weak very fine granular structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, slightly plastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 1% fine faint carbonate nodules in matrix; 5% flat 2- to 150-mm unspecified fragments and 15% 76- to 250-mm unspecified fragments and 40% 2- to 75-mm unspecified fragments; strong effervescence, by HCl, 1 normal; moderately alkaline, pH 7.9; abrupt smooth boundary.

A2—12 to 29 cm: brown (10YR 5/3) extremely bouldery sandy loam, dark brown (10YR 3/3), moist; 63% sand; 17% clay; weak very fine granular structure, and weak fine subangular blocky structure; very friable, soft, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 10% fine faint carbonate nodules in matrix; 9% 2- to 75-mm unspecified fragments and 9% flat 2- to 150-mm unspecified fragments and 11% 76- to 250-mm unspecified fragments and 19% 251- to 600-mm unspecified fragments and 35% 601- to 3000-mm unspecified fragments; violent effervescence, by HCl, 1 normal; moderately alkaline, pH 8.0; gradual smooth boundary.

R—29 cm: limestone bedrock.

Ecology

Johnson and Simon (1987) defined scablands as sites located on gentle ridgetops and characterized by thin, rocky soils populated by drought tolerant plants. The ELSP3-POSE-STENO7 Scabland, Paunsaugunt Family ET is similar to the scablands described by Johnson and Simon (1987) as they are located on low gradient (<20%), windswept, limestone shoulders and summits in shallow to moderately deep, rocky soils. However, Johnson and Simon (1987) consider their bluebunch wheatgrass-Sandberg's bluegrass scabland plant community type to an ecotonal community, whereas the ELSP3-POSE-STENO7 Scabland, Paunsaugunt Family ET is considered to be a topoedaphic climax. The distribution of this ET is strongly controlled by bedrock and topography, occurring where Gallatin and Madison Limestone form extensively weathered ridges. Gallatin and Madison Limestone tend to weather into large flagstones that overlap one another and form a banded pattern when viewed from above. Strong winds intensively erode these sites, leading to expansive wind deflation and an erosion pavement of flagstones that armor the soil surface from further wind erosion. The plant species occurring at these sites are adapted to extensive periods of summer drought and desiccation by wind. Adaptations include a cushion growth-form, enlarged taproots, succulent stems and leaves, and caespitose growth habit. Cushion plants resemble a pincushion in growth-form and avoid wind desiccation and cold temperatures due to a reduced stature and compact stems and leaves. Cushion plants are also capable of strongly adhering to soils in erosive environments, making them extremely effective pioneer species at harsh sites. The enlarged taproots of species such as Cous biscuit-root provide a generous reservoir for water storage. Spearleaf stonecrop features succulent stems and leaves that store water for use during droughty periods. Lastly, some sedges, including spike sedge, feature a caespitose growth habit where individuals form dense, low-growing, clonal tufts that are wind and cold hardy.

Management considerations

The ELSP3-POSE-STENO7 Scabland, Paunsaugunt Family ET is not especially productive as forage grounds for domestic and wild ungulates. Bluebunch wheatgrass growing in patches of deeper soil between flagstones occasionally produces moderate amounts of forage. However, elk, deer, antelope, and domestic cattle and sheep do occasionally utilize this ET as foraging grounds. These sites are tolerant of low levels of trampling. Moderate to heavy trampling can damage the cushion plants and result in the initiation of wind erosion. Risk of trampling damage can be reduced by grazing these sites later in the summer when soils have dried following the flowering of bluebunch wheatgrass (Johnson and Simon 1987).

Similar ecological types

Ecological Type 1

Type: NONE

Table 108—Summary of environmental variables for the ELSP3-POSA12-STENO7 Scabland, Paunsangunt Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,614	2,454	2,697
Slope (%)	12	1	19
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	628	561	672
Degree days	16,450	15,410	18,540
Frost-free days	19.7	19.0	20.7
Site water balance (mm/year)	-330	-411	-277
Average annual temperature (°C)	1.8	1.2	2.7
Total annual potential evapotranspiration (mm)	603	552	687
Summer radiation (KJ)	20,140	19,900	20,400
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	72	62	80
Clay (% in particle size control section)	14	5	21
pH (in particle size control section)	8.0	—	—
Available water capacity (mm/m)	19	3	47
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	3	0	5
Exposed bedrock	3	0	5
Gravel	13	10	20
Cobble	12	10	15
Stones	10	5	15
Boulders	9	2	15
Litter	4	0	10
Wood	0	0	0
Moss and lichen	10	0	22
Basal vegetation	32	25	40
Water	0	0	0

Table 109—Constancy/cover table for common plant species occurring in the ELSP3-POSA12-STENO7 Scabland, Paunsangunt Family ET.

Characteristics	**Species**		**Con**	**Cov**	**Min**	**Max**
				Percent		
Forbs:						
ASMI9	*Astragalus miser*	timber milkvetch	100	2	1	3
BAIN	*Balsamorhiza incana*	hoary balsamroot	67	2	1	3
BEWY	*Besseya wyomingensis*	wyoming kittentail	67	1	1	1
CAPA25	*Castilleja pallescens*	palish Indian-paintbrush	67	1	1	1
DOCO	*Dodecatheon conjugens*	slimpod shooting star	67	1	1	1
ERCA2	*Erigeron caespitosus*	tufted fleabane	67	1	1	1
ERCO24	*Eremogone congesta*	ballhead sandwort	67	1	1	1
ERCOD	*Erigeron compositus* var. *discoideus*	cutleaf daisy	67	1	1	1
LOCO4	*Lomatium cous*	cous biscuit-root	67	6	1	10
MEVI4	*Mertensia viridis*	oblongleaf bluebells	100	2	1	3
OXSE	*Oxytropis sericea*	white locoweed	67	1	1	1
PHHO	*Phlox hoodii*	Hood's phlox	67	2	1	3
PHMU3	*Phlox multiflora*	many-flowered phlox	100	2	1	3
SARH2	*Saxifraga rhomboidea*	diamondleaf saxifrage	67	2	1	3
SELA	*Sedum lanceolatum*	lance-leaved stonecrop	100	2	1	3
STAC	*Stenotus acaulis*	stemless mock goldenweed	67	18	15	20
Grasses:						
ELSP3	*Elymus spicatus*	bluebunch wheatgrass	100	11	3	15
KOMA	*Koeleria macrantha*	prairie junegrass	100	9	3	20
POSE	*Poa secunda*	Sandberg bluegrass	100	17	10	25
Graminoids:						
CANA2	*Carex nardina*	spike sedge	67	6	1	10

Note: Con = A percentage of plots in which a species occurred; Cov = Average canopy cover in plots in which the species occurred.

Miscellaneous Bluebunch Wheatgrass Types

Bluebunch Wheatgrass-Sandberg Bluegrass, Wabek Family Ecological Type

Elymus spicatus-Poa secunda, Wabek Family Ecological Type

ELSP3-POSE, Wabek Family ET

N = 1

The bluebunch wheatgrass-Sandberg bluegrass, Wabek Family Ecological Type occurs within the Granitic Subalpine Zone ecoregion of Chapman and others (2004). This ET occurs on steep (53%), south-facing, granitic glacial till deposits of Pinedale age (Dahms 2004b) along Sinks Canyon in the Middle Fork Popo Agie drainage. It is a component of map unit 351L. Soils were low in coarse fragments (40%), sandy, and low in clay (avg. 10%). Soils were deep, sandy-skeletal Entic Haplustolls.

Potential natural vegetation of this ET is the bluebunch wheatgrass-Sandberg bluegrass habitat type (Tweit and Houston 1980). Antelope bitterbrush and skunkbush sumac sometimes occur as scattered individuals. Bluebunch wheatgrass, Sandberg bluegrass, and arrowleaf balsamroot create a robust herbaceous layer. Prairie junegrass, needle and thread, and gray hawksbeard may also occur. Cheatgrass, western gromwell, and white sagebrush are indicative of recent fire.

The ELSP3-POSE, Wabek Family ET provides important winter range for wild ungulates. Although the forage production of the ET is lower than other non-forested types along the eastern slope of the WRR, these sites melt off early and provide appreciable forage in the spring and early summer. Fires in the ELSP3-POSE, Wabek Family ET are expected to be severe. Land managers should proceed with caution when considering a prescribed burn in this ET. Invasive plant surveys should be conducted prior to any prescribed burn in order to reduce the risk of spreading invasive plants.

Miscellaneous Graminoid Series

Parry’s Rush, Oxyaquic Cryorthents Ecological Type

Juncus parryi, Oxyaquic Cryorthents ET

JUPA, Oxyaquic Cryorthents ET

N = 1

The Parry’s rush, Oxyaquic Cryorthents Ecological Type was located within the Granitic Subalpine Zone ecoregions of Chapman and others (2004). It is a component of map unit 310L. This ET occurred on ground moraines on glacial cirque floors in granitic glacial till at or near tree line. Soils were extremely bouldery (99%), sandy, and saturated within a meter of the soil surface for 20 or more consecutive days or 30 or more cumulative days throughout the growing season, yet lacked redoximorphic features typical of other semi- to permanently saturated soils. Soils were shallow, fragmental, Oxyaquic Cryorthents.

Potential natural vegetation was the Parry’s rush community type. Parry’s rush dominates a rich herbaceous community. Trace amounts of grayleaf willow or grouse whortleberry often occur on drier hummocks. Common forbs include alpine sagebrush, ballhead sandwort, subalpine fleabane, alpine daisy, tundra aster, American bistort, slender cinquefoil, and creeping sibbaldia. White marsh marigold may occur in wet microsites. Alpine timothy, Letterman’s bluegrass, spike trisetum, Falkland island sedge, Raynold’s sedge, and northern singlespike sedge are the most common graminoids.

This ET typically occurs in areas of snow accumulation and may be considered a type of late snowbank vegetation. Soil moisture remains high throughout the growing season due to the slow melting of deep snowdrifts. The Parry’s rush community type is highly productive for grazing animals, especially elk. Thermal and hiding cover are close at hand due to adjacent whitebark pine stands. This ET is tolerant of moderate levels of trampling and grazing, especially later in the season when the soils have dried out. The Parry’s rush, Oxyaquic Cryorthents ET differs from the late snowbank vegetation, Hargran Family ET in that the former occurs at or below timberline, while the latter occurs above timberline.

Riparian and Wetland Series

Principal Species Descriptions

Willow

Salix L.

Introduction

Willows are a diverse group of trees and shrubs that occur in every state and territory of the United States, except Hawaii, and every Canadian Province (USDA NRCS 2007b). The genus *Salix* includes roughly 150 accepted species, 18 accepted subspecies, and 17 accepted varieties (ITIS 2007). Despite the taxonomic diversity of this genus, its members share one important characteristic: a general affinity for abundant soil moisture, lending this genus to occur most often in riparian zones and wetlands. Eight species of willow were common along the eastern slope of the WRR: arctic (*S. arctica* var. *petraea*), snow (*S. reticulata* var. *nana*), grayleaf (*S. glauca* var. *villosa*), planeleaf (*S. planifolia*), Wolf's (*S. wolfii*), Missouri River (*S. eriocephala*), Drummond's (*S. drummondiana*), and Scouler's (*S. scouleriana*) willow. Following is a description of the ecology and management considerations of five of the willow species. Arctic, snow, and grayleaf willows were associated with sites at or above timberline, and as such are treated in the "Alpine Series" section.

General Characteristics

For the following willow species described, regeneration is primarily sexual via small, cottony seeds that germinate rapidly if a moist mineral soil seedbed is attained. All of the following willows reproduce asexually by sprouting from the rootcrown or a damaged stembase. Also, broken stems that become buried in moist substrates will sprout adventitious roots.

Fire is uncommon at the sites inhabited by the species below (with the exception of Scouler's willow). In the rare event of a fire, willows typically resprout quickly from the rootcrown following a low to moderate intensity blaze. Flooding and ungulate browsing are more common forms of disturbance experienced by these species. Periodic flooding is critical for the success of willows by creating fresh mineral soil seedbeds, opening up gaps in the canopy and moistening the soil for successful seed germination. Also, the crowded stems and thick, tangled roots are extremely important in mitigating soil erosion in riparian areas.

Willows constitute a large portion of the diet of wild ungulates, especially moose, but also elk and deer. Domestic livestock readily consume willows. Willows resprout rapidly from the rootcrown or stem base following low to moderate browsing but can become stunted when browsed heavily. Willow is a preferred food and building material of beavers and muskrats. A number of bird species and small mammals take up residence in the dense thickets formed by willow stems.

Principal Species

Planeleaf willow

(*Salix planifolia* Pursh)

Planeleaf willow occurs across the boreal regions of North America, from New England and eastern Canada, west to the southern Yukon Territory and Alaska, and south to California and New Mexico (Uchytil 1991d). On the Shoshone National Forest in Wyoming, planeleaf willow occurs most often in riparian zones and wetlands in the mid- to upper-forested zone between 2,500 and 3,000 m elevation but may occur as low as 1,600 m and as high as 3,800 m (Fertig and Markow 2001). Some authorities recognize two varieties of planeleaf willow, including var. *planifolia*, and var. *monica* (Hitchcock and others 1964). The two varieties have unique growth-forms and have been shown in eastern and central Idaho to inhabit distinctly different ranges along the elevation gradient, the former is a moderately tall shrub (2–4 m) that is found at lower elevation, while the latter is a low shrub (<1 m) that is found at higher elevations (Brunsfeld and Johnson 1985). When this species occurs above timberline, it features a highly reduced growth-form.

Planeleaf willow is a thicket-forming shrub with shiny, reddish to purple twigs and leaves 3 to 5 cm long, lance-elliptic to ovate, shiny green above and glaucous below (Fertig and Markow 2001). The pistillate catkins are typically 1.5 to 5 cm long with hairy capsules, while staminate catkins are 1 to 3 cm long with dark brown to black, long, hairy, flowering bracts. Similar to most other willow species, planeleaf willow is intolerant of shade and prefers soils with a high water table that remain wet within the rooting zone throughout the growing season (Uchytil 1991d). This species often forms dense thickets along streams and lake margins and in wet meadows and seep areas. Soils are typically low in coarse fragments, fine-textured, and often feature a thick (>30 cm) organic horizon over mineral soil.

Wolf's willow

Salix wolfii Bebb

Wolf's willow occurs throughout the central and southern Rocky Mountains from northeastern Oregon and southwestern Montana, south through central and western Wyoming, northeastern Utah, and northern Nevada, to central and western Colorado and northern New Mexico (USDA NRCS 2007b). On the Shoshone National Forest, Wolf's willow is most commonly associated with montane and subalpine wet meadows, streamsides, and fens between 2,292 and 3,182 m (Massatti 2007). Two varieties of Wolf's willow, var. *idahoensis* and var. *wolfii*, occur on the Shoshone National Forest with the former occurring near the upper end of the above elevation range (2,951-3,182 m) and the latter near the lower end (2,292-3,122 m) (Massatti

2007). While the habitat preference of Wolf's willow is somewhat broad, it tends to prefer soils that are drier or better drained than those occupied by planeleaf willow (Brunsfeld and Johnson 1985). However, Wolf's and planeleaf willows commonly co-occur, especially within the middle to low elevation range of the two species. Wolf's willow is a low shrub averaging 1 m tall with elliptic, gray-green, silvery-pubescent leaves (Fertig and Markow 2001). The pistillate catkins are typically 0.8 to 2 cm long with pubescent (var. *idahoensis*) or glabrous (var. *wolfii*) capsules. The staminate catkins are 1 to 2 cm long with dark brown to black, wooly-pubescent flowering bracts.

Missouri River Willow

Salix eriocephala Michx.

Missouri River willow occurs from California and eastern Oregon in the west to Montana, Wyoming, and New Mexico in the south and east (Fertig and Markow 2001). On the Shoshone National Forest, Missouri River willow is most commonly associated with streambanks and floodplains in the mid- to lower-forested zone between 1,859 and 2,564 m (Massatti 2007) but may occur as low as 1,700 m (Fertig and Markow 2001).

Missouri River willow is a medium to tall shrub with lance-shaped to ovate leaves that are slightly toothed, contract abruptly to the petiole, and are dark green above and glaucous beneath (Fertig and Markow 2001). The pistillate catkins are typically 1 to 6 cm long on leafy branchlets with glabrous capsules attached to a white-wooly rachis. The staminate catkins are 2 to 5.2 cm long with dark brown to black, glabrate flowering bracts.

Drummond's Willow

Salix drummondiana Barratt ex Hook.

Drummond's willow occurs through western North America from the Yukon Territory south through inland British Columbia, Washington, Oregon, and California and in all western states except Arizona (Uchytil 1991c; USDA NRCS 2007b). On the Shoshone National Forest, Missouri River willow most commonly occurs in the mid- to upper-forested zone between 2,530 and 3,079 m but may occur as low as 2,012 m and as high as 3,521 m (Fertig and Markow 2001; Massatti 2007). At the lowest elevation, Drummond's willow is confined to the edges of streams, while at higher elevations, it occurs across a broader range of habitats, including moist meadows, seeps, and stream and pond margins (Uchytil 1991c). Drummond's willow prefers moist, well-aerated mineral soils. Drummond's willow is a medium to tall shrub with finely pubescent twigs and narrowly elliptic to lanceolate, slightly involute leaves that are dark green above and densely silvery pubescent below (Fertig and Markow 2001). The pistillate catkins are typically 1.5 to 4.5 cm long and sessile or nearly so with densely short-hairy capsules. The staminate catkins are sessile and 1.5 to 3 cm long with dark brown to black, pubescent flowering bracts.

Scouler's Willow

Salix scouleriana Barratt ex Hook.

Scouler's willow is a widespread species that occurs throughout western North America, from Alaska and Yukon Territory south through all of the western states, into the mountains of northern Mexico, and east into the Black Hills of western South Dakota (Anderson 2001b). Scouler's willow is a highly adaptable species, occurring on the Shoshone National Forest across a broad range of elevations (1,372–3,262 m) from the sagebrush zone to upper timberline (Fertig and Markow 2001). It is often found growing on upland sites in Douglas-fir, subalpine fir, and Engelmann spruce forests and may sometimes be found in riparian areas and wetlands (Anderson 2001b). Scouler's willow prefers moderately well-drained to well-drained soils that are usually somewhat drier than those preferred by other willow species.

Scouler's willow is a tall shrub or small tree with large (3–8 cm), elliptic to ovate leaves that are green above and glaucous below (Fertig and Markow 2001). The pistillate catkins are typically 1.5 to 5 cm long and sessile or on short branchlets. The staminate catkins are sessile and 1 to 3 cm long and feature dark brown to black flowering bracts with long, silky hairs. Similar to most other willow species, Scouler's willow is intolerant of shade, and at forested sites, shows the greatest regeneration immediately following a disturbance event (Anderson 2001b). Fire is more important at sites inhabited by Scouler's willow than the moist riparian and wetland sites typical of most other willow species. Following low to moderate degree burns, Scouler's willow responds rapidly by sprouting from the root crown. On severely burned sites with high coverage of exposed mineral soil, regeneration is limited to airborne seeds.

Willow/Sedge, Moose River Family Ecological Type

Salix/*Carex*, Moose River Family ET

SALIX/CAREX, Moose River Family ET

N = 9

Distribution

The willow/sedge, Moose River Family Ecological Type occurs in the study area within the granitic subalpine and alpine zone ecoregions of Chapman and others (2004). The ecological type occurs along riparian zones and in wetlands in soil derived at least in part from granitic alluvium. It is a component of map unit 302 and 302L.

Environment

Aspect: east-southeast [1], north [1], northeast [1], north-northeast [1], south [2], southeast [1], south-southeast [1], west-northwest [1].

Landforms and Landscape Position: Toeslopes. Floodplains, seeps, fens, cobble bars, moist/wet meadows.

Parent Materials: Mixed granitic alluvium.

In the southern portion of the study area, south of the North Fork Popo Agie River, parent material tends to be alluvium derived from granodiorite of the Louis Lake Pluton. In the southern portion of the study area in the areas north of and including the North Fork Popo Agie River, parent material tends to be alluvium derived from porphyritic quartz monzonite. In the northern portion of the WRR, parent materials tend to be mixed migmatite and gneiss alluvium.

Bedrock: Precambrian granodiorite, porphyritic quartz monzonite, gneiss, and migmatite.

Climate: Cryic temperature regime and Aquic moisture regime. Estimated annual precipitation ranges from 62 to 81 cm.

Additional environment data summaries are provided in Table 110.

Potential natural vegetation

This ecological type includes a variety of riparian and wetland plant communities. Potential natural vegetation includes Wolf's willow/inflated sedge, Wolf's willow/tufted hairgrass (Walford and others 2001), planeleaf willow/bluejoint reedgrass, planeleaf willow/Holm's Rocky Mountain sedge (Walford and others 2001), Drummond's willow/mesic forb, Drummond's willow/bluejoint reedgrass, inflated sedge, and tufted hairgrass (Walford and others 2001). Table 111 provides a summary of species constancy and cover for the planeleaf willow/Holm's Rocky Mountain sedge community type.

Wolf's willow/inflated sedge community type (n = 1): This type occurred on a floodplain along Rock Creek in Grannier Meadows. Wolf's, planeleaf, and Geyer willows occur on soil mounds, creating a dense medium to tall shrub canopy. Inflated sedge forms a dense sward, occurring between mounds and in abandoned stream channels, and leaving little space for other herbaceous species to reach high abundance. Other species that occur scattered throughout the understory include varileaf cinquefoil, red-pod stonecrop, largeleaf avens, meadow sedge, tufted hairgrass, and bluejoint reedgrass.

Wolf's willow/tufted hairgrass community type (n = 1): This type occurred on a floodplain along Dinwoody Creek in Wilson Meadows. Wolf's and planeleaf willows occur on soil mounds forming a thick moderately tall shrub canopy. Tufted hairgrass occurs scattered across the mounds along with a diversity of species, including western yarrow, varileaf cinquefoil, western mountain aster, American alpine speedwell, tall fringed bluebells, Rocky Mountain groundsel, spike trisetum, Holm's Rocky Mountain sedge, Wheeler's bluegrass, Falkland island sedge, and Kentucky bluegrass. The area between the mounds remained flooded for most of the year, and the only species occurring with appreciable coverage were northern reedgrass and silvery sedge.

Planeleaf willow/bluejoint reedgrass community type (n = 1): This type occurred in a complex of small stream channels created by melting snow from a nivation hollow at Burro Flat in the northern WRR. Planeleaf willow forms a nearly impenetrable low to moderately tall shrub layer. Bluejoint reedgrass, tufted hairgrass, smallflowered woodrush, fireweed, and western yarrow occurred in slightly drier portions of the site. Brook saxifrage and tall fringed bluebells were found growing along active stream channels, while Merten's rush, mud sedge, and hairy arnica were found in the wettest portions of the site.

Planeleaf willow/Holm's Rocky Mountain sedge community type (n = 2): This type occurred in a fen located near Coon Lake and on a seepy floodplain along the North Fork Popo Agie river near Lonesome Lake. Planeleaf willow occurs in the wettest portions of the plot, forming a moderately dense shrub layer. Grayleaf willow and alpine laurel sometimes occur on the slightly drier microsites. Holm's Rocky Mountain sedge, white marsh marigold, and water speedwell occur in wetter portions of the site. Other common species include varileaf cinquefoil, red-pod stonecrop, elephant's head, American alpine speedwell, alpine bentgrass, and water ragwort. Black alpine sedge, alpine timothy, and subalpine fleabane are generally limited to drier microsites.

Drummond's willow/mesic forb community type (n = 1): This type occurred on a cobble bar along a moderately steep (4%) tributary to the North Fork Popo Agie River near Lizardhead Meadow. Drummond's, Wolf's, and plane-leaf willows occur jointly, forming a dense medium to tall shrub layer. Prickly currant occurs scattered throughout the willow overstory. Arrowleaf groundsel, tall fringed bluebells, brook saxifrage, and fringed grass-of-Parnassus occur on or near the active stream channel. Common cowparsnip, sticky purple geranium, Colorado blue columbine, manyray goldenrod, and subalpine fleabane occur on drier microsites further from the stream channel. Common graminoids include Letterman's needlegrass in drier microsites and bluejoint reedgrass in wet microsites.

Drummond's willow/bluejoint reedgrass community type (n = 1): This type occurred in a large fen along Slate Creek. Drummond's and Tweedy's willows were found growing in large clumps on soil mounds forming an open tall shrub layer. Canadian gooseberry and bog birch were found growing among the willow clumps. Bluejoint reedgrass forms a dense tall graminoid layer punctuated by beaked sedge and aquatic sedge in wet microsites. Other herbaceous species occurred as scattered individuals, including glaucus willowherb, largeleaf avens, fireweed, arrowleaf groundsel, field horsetail, swordleaf rush, and Kentucky bluegrass. Pink wintergreen and Fendler's meadow-rue were found growing on soil mounds beneath the willow clumps.

Inflated sedge community type (n = 1): This type occurred on a floodplain of the Middle Fork Popo Agie River at Bills Park. Aquatic, inflated, and Sierra hare sedge form a dense sward. Holm's Rocky Mountain sedge and tufted hairgrass occur on slightly drier microsites. Narrow-spiked reedgrass and silvery sedge occur at low abundance in the wettest portions of the site.

Tufted hairgrass community type (n = 1): This type occurred on a floodplain of the Middle Fork Popo Agie River at Tayo Park. Tufted hairgrass and alpine timothy form a moderately dense moist meadow. Aquatic, inflated, and beaked sedge occur in wet microsites. A variety of subalpine forbs occur in this type, including American alpine speedwell, varileaf cinquefoil, subalpine fleabane, elephant's head, cleftleaf groundsel, and western yarrow. Kentucky bluegrass occurs in this type, most likely the result of horse pasturing at this site.

Soils

On landforms with slope ≤3% (see "Typical Pedon Description" below), soils in the Salix/Carex, Moose River

Family ET were deep, and aquic conditions were always present (avg. 87 cm depth). Coarse fragments (0–46%, avg. 24%) and clay (10–32%, avg. 17%) were highly variable within and between soil profiles. The soils showed strong evidence of periodic flooding, including buried soil horizons and thin layers and pockets of gravel and sand within fine-textured mineral soil horizons. Redoximorphic features were also common within 100 cm of the mineral soil surface. Although the soils in this ET are highly variable due to their fluvial nature, they do share a number of common characteristics. A typical soil features an A/Bg/Ab/C horizonation. C-horizons tended to be sandy or gravelly. Sandy Bw-horizons occurred periodically throughout the soil profiles, indicating separate flood events. One soil featured a 21-cm thick Bt-horizon directly beneath the A-horizon. Diagnostic soil horizons include mollic (avg. 33 cm thick), umbric (avg. 32 cm thick), or ochric (avg. 20 cm thick) epipedons. Particle size class included loamy-skeletal [1], coarse-loamy [3], sandy-skeletal [2], and fine-silty [1]. Soils were Typic Cryaquents [4], Typic Cryaqualfs [1], Typic Cryaquolls [1], and Fluvaquentic Cryaquepts [1].

On landforms with slope >3%, soils in the Salix/Carex, Moose River Family ET were deep, and aquic conditions were sometimes present. Coarse fragments (23–81%, avg. 52%) and clay (4–21%, avg. 13%) were highly variable within and between soil profiles. The soils showed strong evidence of periodic flooding, including buried soil horizons and thin layers and pockets of gravel and sand within fine-textured mineral soil horizons. Redoximorphic features were absent within 100 cm of the mineral soil surface. A typical soil features an A/C/Ab horizonation. Diagnostic soil horizons include an ochric (19 cm thick) or histic

(28 cm thick) epipedon. Particle size class included fine-loamy [1] and sandy-skeletal [1]. Soils were Mollic Cryofluvents [1] and Histic Cryaquepts [1].

Typical pedon description

Soil Classification: Coarse-loamy, mixed, superactive, acid Typic Cryaquents

A1—0 to 8 cm: very dark brown (10YR 2/2) fine sandy loam, dark grayish brown (10YR 4/2), dry; 52% sand; 10% clay; moderate medium subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and many very fine roots; common fine and common medium and many very fine pores; 3% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.2; clear smooth boundary.

A2—8 to 14 cm: dark brown (10YR 3/3) loam, brown (10YR 5/3), dry; 45% sand; 12% clay; moderate fine subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 5% faint yellowish brown (10YR 5/6), dry, masses of oxidized iron on faces of peds; 4% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 5.0; clear smooth boundary.

Bw—14 to 25 cm: very dark grayish brown (10YR 3/2) loam, pale brown (10YR 6/3), dry; 38% sand; 15% clay; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 12% faint brownish yellow (10YR 6/6), dry, and dark yellowish brown (10YR 3/4), moist, masses of oxidized iron on faces of peds; 10% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.8; abrupt smooth boundary.

2Abg—25 to 31 cm: dark grayish brown (2.5Y 4/2) loam, gray (2.5Y 6/1), dry; 39% sand; 21% clay; moderate coarse subangular blocky structure parting to moderate fine subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; common fine roots and common medium roots and common very fine roots; common fine and common medium and common very fine pores; 23% distinct yellowish brown (10YR 5/8), dry, and dark yellowish brown (10YR 3/6), moist, masses of oxidized iron on faces of peds; 8% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 4.9; abrupt smooth boundary.

2Bwb—31 to 38 cm: dark yellowish brown (10YR 3/6) medium gravelly coarse sandy loam, light yellowish brown (10YR 6/4), dry; 74% sand; 6% clay; weak fine subangular blocky structure, and moderate fine granular structure; very friable, slightly hard, slightly sticky, nonplastic; common fine roots and common very fine roots; common medium and common very fine pores; 9% faint yellowish brown (10YR 5/6), dry, and dark yellowish brown (10YR 4/4), moist, masses of oxidized iron on faces of peds; 26% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; strongly acid, pH 5.4; abrupt smooth boundary.

3Ab1—38 to 57 cm: very dark grayish brown (10YR 3/2) loam, pale brown (10YR 6/3), dry; 41percent sand; 20% clay; moderate medium subangular blocky structure parting to moderate very fine subangular blocky structure; friable, moderately hard, moderately sticky, nonplastic; common fine roots and common very fine roots; common fine and common medium and common very fine pores; 15% faint yellowish brown (10YR 5/6), dry, and dark yellowish brown (10YR 4/4), moist, masses of oxidized iron on faces of peds; 3% 2- to75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 5.0; clear smooth boundary.

4Ab2—57 to 72 cm: dark olive brown (2.5Y 3/3) loam, grayish brown (2.5Y 5/2), dry; 41% sand; 22% clay; moderate coarse subangular blocky structure parting to moderate very fine subangular blocky structure; friable, slightly hard, moderately sticky, nonplastic; common fine roots and common very fine roots; common fine and common very fine pores; 7% faint yellowish brown (10YR 5/8), dry, and dark yellowish brown (10YR 3/6), moist, masses of oxidized iron on faces of peds; 8% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 5.0; clear smooth boundary.

5C—72 to 102 cm: dark olive brown (2.5Y 3/3) very gravelly coarse sandy loam, light yellowish brown (2.5Y 6/3), dry; 72% sand; 12% clay; weak medium subangular blocky structure; friable, slightly hard, slightly sticky, nonplastic; few fine roots and few very fine roots; common fine and common medium and common very fine pores; 10% faint yellowish brown (10YR 5/8), dry, and dark yellowish brown (10YR 3/6), moist, masses of oxidized iron on faces of peds; 46% 2- to 75-mm unspecified fragments; noneffervescent, by HCl, 1 normal; very strongly acid, pH 5.0.

Ecology

The willow/sedge, Moose River Family ET represents riparian and wetland plant communities occurring on floodplains, seeps, fens, cobblebars, and moist/wet meadows. The soils are typically permanently saturated and minimally developed, in large part due to a continual influx of sandy alluvium to the site. Flooding typically occurs each spring and continues until melt off. Willows feature several adaptations to periodic flooding, including strong flexible stems, an ability to resprout from broken or buried stems, and buoyant seeds (Karrenberg and others 2002). Sedges adapted to permanent soil saturation, including aquatic, bladder, and inflated, feature large hollow cells (aerenchymous tissue) in the roots to store air for metabolic use during periods of inundation (Kozlowski 1984).

Management considerations

In the Rocky Mountains, riparian zones, and wetlands, although encompassing only a small fraction of the surface area of the Earth, are exponentially important as epicenters of biodiversity, travel corridors for fish and wildlife, and a ready source of food and water for wildlife in a predominantly arid landscape. Riparian and wetland vegetation intercepts solar radiation, thus shading stream waters and maintaining cooler water temperatures—conditions necessary for the health and survival of salmonid populations (Wells 2006). Riparian and wetland vegetation also provides habitat for salmonids through overhanging stems and leaves. Many species of wildlife depend on riparian zones and wetlands for essential habitat, including moose, elk, sandhill cranes, muskrats, beavers, and a variety of reptiles and amphibians. In fact, willows are a highly preferred and nutritious browse for moose and elk. The strong stems and dense, tangled roots of willows and sedges physically buffer streambanks from the erosive power of spring flood events.

The most important management consideration for the willow/sedge, Moose River Family ET is cattle grazing. These riparian and wetland communitiy types are best grazed later in the summer after the soils have begun to dry. Grazing when the soils are wet will result in increased trampling, destruction of the dense sod created by sedge roots, and the initiation of soil erosion. Community types featuring tufted hairgrass or bluejoint reedgrass, including the planeleaf willow/bluejoint reedgrass, Drummond's willow/bluejoint reedgrass, Wolf's willow/tufted hairgrass, and tufted hairgrass community types, are highly preferred by cattle due to the relatively well-drained soils and abundance of highly palatable grasses. Prolonged grazing can lead to an increase in less palatable species, including Kentucky bluegrass and Baltic rush, at the expense of tufted hairgrass and bluejoint reedgrass (Walford and others 2001). Prolonged grazing in the planeleaf willow/Holm's Rocky Mountain sedge, Wolf's willow/inflated sedge, and inflated sedge community types may result in a decrease in the abundance of sedges, and an increase in tufted hairgrass, Kentucky bluegrass, and forbs. When logging adjacent upland forests, buffer strips of forested vegetation along riparian and wetland areas should be left intact in order to mitigate the effects of increased run-off on soil erosion and sedimentation following timber harvest operations.

Similar ecological types

Ecological Type 1

Type: Oxyaquic soils, Elvick Family ET

Floristic differences: A number of vegetation types constitute the, Elvick Family ET, including some of those listed under the Moose River Family ET.

Environmental differences: The two types differ environmentally in that the Moose River Family ET soils are saturated within a meter of the soil surface throughout the growing season and feature characteristic redoximorphic features, whereas the Elvick Family ET soils are saturated within a meter of the soil surface for 20 or more consecutive days or 30 or more cumulative days throughout the growing season, yet lack redoximorphic features typical of other semi- to permanently saturated soils.

Table 110—Summary of environmental variables for the Salix/Carex, Moose River Family ET.

General environment:	**Average**	**Min**	**Max**
Elevation (m)	2,969	2,630	3,271
Slope (%)	3	1	6
Climate:	**Average**	**Min**	**Max**
Average annual precipitation (mm)	716	619	805
Degree days	12,190	8,862	16,040
Frost-free days	17.6	15.8	19.5
Site water balance (mm/year)	-148	-256	-82
Average annual temperature (°C)	0.0	-1.5	1.6
Total annual potential evapotranspiration (mm)	489	399	627
Summer radiation (KJ)	20,300	18,720	20,840
Soils:	**Average**	**Min**	**Max**
Coarse fragments (% in particle size control section)	30	0	81
Clay (% in particle size control section)	15	4	32
Ph (in particle size control section)	4.9	4.6	5.3
Available water capacity (mm/m)	104	29	159
Ground surface components, cover:	**Average**	**Min**	**Max**
Exposed soil; < 2mm fraction (%)	1	0	2
Exposed bedrock	0	0	0
Gravel	1	0	5
Cobble	1	0	10
Stones	1	0	5
Boulders	0	0	0
Litter	31	10	50
Wood	1	0	5
Moss and lichen	7	2	16
Basal vegetation	53	25	70
Water	3	0	15

Table 111—Constancy/cover table for common plant species occurring in the Salix/Carex Moose River Family ET, planeleaf willow/Holm's Rocky Mountain sedge community type.

Characteristic	Species		Con	Cov	Min	Max
				Percent		
Seedlings:						
ABLA	*Abies lasiocarpa*	subalpine fir	100	3	1	5
PIEN	*Picea engelmannii*	Engelmann spruce	100	1	1	1
Shrubs:						
SAPL2	*Salix planifolia*	planeleaf willow	100	75	75	75
Forbs:						
CALE4	*Caltha leptosepala*	white marsh marigold	100	6	3	10
PODI2	*Potentilla diversifolia*	varileaf cinquefoil	100	3	3	3
SEHY2	*Senecio hydrophilus*	water ragwort	100	6	3	10
Grasses:						
PHAL2	*Phleum alpinum*	alpine timothy	100	1	1	1
Graminoids:						
CANI2	*Carex nigricans*	black alpine sedge	100	6	1	10
CASC12	*Carex scopulorum*	Holm's Rocky Mountain sedge	100	15	15	15

Note: Con = A percentage of plots in this ET in which the species occurred; Cov = Average canopy cover in plots in which the species occurred, Min = minimum canopy cover in plots in which the species occurred, Max = maximum canopy cover in plots in which the species occurred.

Miscellaneous Riparian and Wetland Types

Willow/Sedge—Kettle Lake, Fluvaquentic Cryaquepts Ecological Type

Salix/Carex–Kettle Lake, Fluvaquentic Cryaquepts ET

SALIX/CAREX – Kettle Lake, Fluvaquentic Cryaquepts ET

N = 1

The willow/sedge–kettle lake, Fluvaquentic Cryaquepts Ecological Type occurs within the granitic subalpine zone of Chapman and others (2004). It is a component of map unit 327L. This ET occurs on the periphery of kettle lakes in the Louis Lake moraine unit in granitic alluvium and lacustrine sediments. Soils were deep, sandy, and aquic; low in rock fragments (35%); and clay (12%). Redoximorphic features and buried horizons were common. Soils were loamy-skeletal, Fluvaquentic Cryaquepts. Wolf's, planeleaf, and Geyer willows occur on soil mounds, creating a dense medium to tall shrub canopy. Inflated sedge forms a dense sward, occurring between mounds, leaving little space for other herbaceous species to reach high abundance. Other species that occur scattered throughout the understory include varileaf cinquefoil, red-pod stonecrop, largeleaf avens, meadow sedge, tufted hairgrass, and bluejoint reedgrass.

This ecological type provides important habitat for moose, songbirds, amphibians, and reptiles, and abundant water and browsing/grazing opportunities in a landscape dominated by unproductive (in terms of graze/browse) lodgepole pine and whitebark pine forests.

Oxyaquic Soils, Elvick Family Ecological Type

Oxyaquic Soils, Elvick Family ET

N = 2

The Oxyaquic soils, Elvick Family Ecological Type was located within the Alpine Zone and Granitic Subalpine Zone ecoregions of Chapman and others (2004). It is a component of map unit 302. This ET occurred in riparian zones and wetlands in granitic alluvium. Elevation ranged between 2691 and 3261 m. Average annual precipitation ranged between 64 and 83 cm. Parent materials were granitic alluvium. Soils were deep, loamy skeletal, Oxyaquic Eutrocryepts, and Oxyaquic Haplocryolls.

The potential natural vegetation included the tufted hairgrass (Walford and others 2001) and planeleaf willow/Holm's Rocky Mountain sedge community types. The tufted hairgrass community type occurred in a moist meadow along Rock Creek in Grannier Meadows. Tufted hairgrass, alpine timothy, Hall's rush, and small-winged sedge combine to form a dense sward along with a variety of other forbs and graminoids, including red avens, American bistort, western yarrow, glandular willow-herb, varileaf cinquefoil, timber oatgrass, Holm's Rocky Mountain sedge, western mountain aster, tickle-grass, and slender wheatgrass. Water sedge, hairy arnica, narrow-spiked reedgrass, Hayden's sedge, and western dock were found in wet microsites. Field chickweed and Kentucky bluegrass are weedy species indicative of horse pasturing in this meadow.

The planeleaf willow/Holm's Rocky Mountain sedge community type occurred in a wetland in Ice Lakes cirque. Planeleaf willow forms a diffuse low shrub layer. Cascade willow, a low-growing miniature willow, occurs throughout the site forming a dense, net-like ground cover. Fewflower spikerush and white marsh marigold occur in the wettest portions of the site. Tufted hairgrass, elephant's head, American bistort, American alpine speedwell, Holm's Rocky Mountain sedge, vivparous knotweed, and diamondleaf saxifrage are common species in moist soils. Alpine timothy, subalpine fleabane, alpine sagebrush, Ross's avens, bog blueberry, tundra aster, Columbian stitchwort, and Rocky mountain fescue may be found on drier microsites.

The soils in the Oxyaquic soils, Elvick Family ET are saturated with water within a meter of the soil surface for 20 or more consecutive days or 30 or more cumulative days throughout the growing season, yet lack redoximorphic features typical of other semi- to permanently saturated soils. The tufted hairgrass community type is highly productive for grazing animals. Early in the summer when still wet, these soils are easily damaged by even low levels of trampling. These sites are best grazed at low levels later in the summer after the soils have begun to dry. Grazing should be avoided, and land managers should encourage backpackers and wranglers to avoid traveling across this ET, especially in the Alpine Zone ecoregion.

A number of vegetation types constitute the Oxyaquic soils, Elvick Family ET, including some of those listed under the late snowbank vegetation, Hargran Family ET. However, the two types differ environmentally in that the Hargran Family ET occurs above timberline and is associated with late snowbank environments, while the Elvick Family ET occurs in riparian zones and wetlands either above or below timberline.

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Glossary

The following glossary provides definitions for technical terms used throughout this document. The definitions were obtained from a variety of sources. Definitions from sources listed in the "Bibliography" section of this document are cited using standard in text citations (e.g., Dorn, 2001). The reader is directed to the "Bibliography" for the full citations. Definitions from sources not included in the "Bibliography" section have been given reference codes (see below) that are used to denote the source of the definition. Permission was granted to Aaron Wells by the American Geological Institute (AGI) to use various definitions. Permission was granted to Aaron Wells by the Soil Science Society of America (SSSA) to use various definitions. Modifications from original AGI and SSSA definitions are indicated by underlining the reference code.

Reference Codes

AGI—Neuendorf, K.K.E; J.P. Mehl, Jr.; and J.A. Jackson. 2005. Glossary of Geology, 5th Edition. Alexandria, VA: American Geological Institute. 800 p. Available: http://www.agiweb.org/pubs/glossary [2012, April 15]. © 2005 Glossary of Geology, published by the American Geological Institute and used with their permission. See www.agiweb.org/pubs for more.

NOAA—National Oceanic and Atmospheric Association (NOAA). 2008. Online climate glossary. Climate Program Office. Available: http://www.climate.noaa.gov/index.jsp?pg=page_glossary.jsp?alpha=all [2012, April 15].

NRCS—U.S. Department of Agriculture, Natural Resources Conservation Service, 2007. National Soil Survey Handbook, title 430-VI. Available: http://soils.usda.gov/technical/handbook/ [2012, April 15].

PF—Pough, F.H. 1991. Peterson first guides: Rocks and minerals. New York, NY: Houghton Mifflin Company. 128 p.

SSSA—Soil Science Society of America (SSSA). 2008. Glossary of soil science terms. Soil Science Society of America, Madison, WI. Available: https://www.soils.org/publications/soils-glossary [2012, April 15].

WC—Wikipedia contributors (WC). 2008. Diabase. Wikipedia Foundation, Inc. Available: http://en.wikipedia.org/wiki/Diabase [2012, April 15].

A

albite—A feldspar with the chemical composition $NaAlSi_3O_8$ (PF).

alluvium—Unconsolidated, clastic material subaerially deposited by running water, including gravel, sand, silt, clay, and various mixtures of these (NRCS).

alpine—The area above the upper limits of (erect) tree growth (Wells 2006).

alpine turf—Alpine plant communities with a more continuous coverage of plants, and a lower percentage of rocks and erosion pavement at the soils surface than alpine fellfields (Johnson 2004).

amphibole—A large group of rock-forming calcium, iron, magnesium, and aluminum silicates. Amphiboles are similar to pyroxenes, but contain water (PF).

anaerobic—A condition characterized by the absence of free oxygen (Wells 2006).

annual—A plant that lives only one growing season and usually has a slender taproot or few fibrous roots (Dorn 2001).

anticline—A convex fold in rock, the central part of which contains the oldest section of rock (Chernicoff and others 1997).

aquic (soil moisture regime)—A reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated by water (Soil Survey Staff 2003).

aspect—The compass direction (in degrees and accounting for declination) that a slope faces, looking downslope (in the direction that overland water would flow) (Schoeneberger and others 2002).

available water capacity (AWC)—An estimate of the water available to plants between permanent wilting point and field capacity after hydric soils have been drained by gravity (Wells 2006).

avalanche—A large mass of snow, ice, soil, or rock, or mixtures of these materials, falling, sliding, or flowing very rapidly under the force of gravity. Velocities may sometime exceed 500 km/hr (Schoeneberger and others 2002).

avalanche chute—The central channel-like corridor, scar, or depression along which at avalanche has moved. An eroded surface marked by pits, scratches, and grooves (Schoeneberger and Wysocki 2002).

average cover—The average percentage canopy cover of a species for the sample stands where it was recorded. For example, a vegetation type may be composed of 12 sample stands, but a particular species may be present in only 5 of those stands. The average cover for that species is calculated as the average canopy cover in those 5 stands (Wells 2006).

B

backslope—The hill slope profile position that forms the steepest and generally linear, middle portion of the slope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below. They may or may not include cliffs or rock outcrop. Backslopes are commonly erosional forms produced by mass movement, colluvial action, and running water; compare summit, shoulder, footslope, and toeslope (Schoeneberger and Wysocki 2002).

bank or streambank—The sloping land bordering a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel (Wells 2006).

basal area—The area of the cross section of a tree trunk 1.37 m above the ground, usually expressed as the sum of tree basal areas in square meters per hectare (Wells 2006).

basal vegetation (ground cover estimates)—Basal vegetation is the soil surface occupied by live basal or root crown portion of vascular plants, including live trees. Typically ranges between 3 and 7%; 15% is very high and rarely encountered (Winthers and others 2005).

basalt—A general term for dark-colored mafic igneous rocks, commonly extrusive but locally intrusive (e.g., as dikes), composed chiefly of calcium-rich plagioclase and pyroxenes; the fine-grained equivalent of gabbro (AGI).

basement (rock)— The crust of the Earth below sedimentary deposits. (AGI).

batholith—A massive discordant pluton with a surface area greater than 100 km^2, typically having a depth of about 30 km. Batholiths are generally found in elongate mountain ranges after the country rock above them has eroded (Chernicoff and others 1997).

bedrock—A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Winthers and others 2005). See also "lithic contact."

biennial—A plant that lives for two growing seasons, usually forming a basal rosette of leaves the first season but not flowering until the second (Dorn 2001).

biotite—An iron-rich muscovite mica that is black in color (Pough 1991).

boulder—Rock fragments greater than or equal to 600 mm in diameter (Winthers and others 2005).

browse—Shrubby or woody forage used especially by big game (Wells 2006).

C

caespitose—Grows in tufts (Dorn 2001).

calcite—A common rock-forming mineral: $CaCO_3$. Calcite is usually white, colorless, or pale shades of gray, yellow, and blue; it a vitreous lustet, and it readily effervesces in cold dilute hydrochloric acid. It is the principal constituent of limestone (AGI).

calcium carbonate or carbonate—See "calcite."

calcareous—Of or pertaining to calcite. Often used as an adjective when describing soils with high concentrations of calcite.

canyon—A long, deep, narrow, very-steep sided valley with high and precipitous walls in an area of high local relief (Wells 2006).

chert—A hard, extremely dense or compact, dull to semivitreous, microcrystalline sedimentary rock, consisting dominantly of interlocking crystals of quartz less than about 0.03 mm in diameter; it may contain amorphous silica (opal). It sometimes contains impurities such as calcite, iron oxide, and the remains of siliceous and other organisms. It has a tough, splintery to conchoidal fracture, and may be white or variously colored gray, green, blue, pink, red, yellow, brown, and black. Chert occurs principally as nodular or concretionary segregations (chert nodules) in limestones and dolomites (AGI).

cirque or glacial cirque—A deep steep-walled half-bowl-like recess or hollow, variously described as horseshoe- or crescent-shaped or semicircular in plan, situated high on the side of a mountain and commonly at the head of a glacial valley, and produced by the erosive activity of a mountain glacier. It often contains a small round lake, and it may or may not be occupied by ice or snow. French, from Latin "circus," "ring" (AGI).

classification—The orderly arrangement of objects according to their differences and similarities.

clay—Soil particles less than 0.002 mm in diameter, see also "soil separates." As a textural class, soil material that contains 40% or more clay, <45% sand, and <40% (SSSA).

clay films—Coatings of oriented clay on the surfaces of peds and mineral grains and lining pores. Also called clay skins, clay flows, illuviation cutans, or argillans (SSSA).

claystone—(a) An indurated sedimentary rock with more than 67% clay-sized minerals, (b) An indurated clay having the texture and composition of shale but lacking its fine lamination or fissility; a massive mudstone in which clay predominates over silt (AGI).

cleavage—The tendency of certain minerals to break along distinct planes in their underlying crystal structure where the bonds are weakest (Chernicoff and others 1997).

climate change—Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (IPCC 2007).

climax—Climax has been defined as the kind of plant community that will come to occupy a site under existing hydrology (flooding regime and mean annual water table depth ranges), soils (parent material, particle size, chemistry), microclimate and fluvial surface. It is the "stable state" where change in the vegetation is minimal over time and competition is so great from prevailing species that "invaders" are excluded and "increasers" are held to low levels. The plant association is the climax plant community on a site (Crowe and Clausnitzer 1997).

climax species—A species that is self-regenerating, in the absence of change in the hydrology, soils, and microclimate (see "climax") with no evidence of replacement by other species.

cobble—Rock fragments greater than or equal to 75 mm and less than 250 mm in diameter (Winthers and others 2005).

cobble bar, bar, gravel bar, or rocky bar—A general term for a ridgelike accumulation of sand, gravel, or other alluvial material formed in the channel, along the banks, or at the mouth of a stream where a decrease in velocity induces deposition: e.g., a channel bar or a meander bar (Wells 2006).

cold air drainage—The result of temperature inversions in areas of significant topographic relief when at night cooler air of upper slopes, having greater density than warmer air, drains down ravines and slides under the mass of warm air which has accumulated in the valley during the day (Lee 1978).

colluvial—Pertaining to material transported and deposited by gravitational action and local unconcentrated runoff on and at the base of steep slopes (Schoeneberger and Wysocki 2002).

colluvium—Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff (Schoeneberger and Wysocki 2002).

component or soil map unit component—Describes the properties of natural bodies of soils in a particular landscape (National Soil Survey Center 2003). An individual component within a soil map unit embodies a collection of similar soils that represent a significant percentage of the land area of a soil map unit, and occur repetitively across the landscape. The two types of components are: major and minor.

major component—A map unit component composing >10% of the areal extent of a map unit. A minimum of three sample points was required to define a major component. However, less than three sample points may constitute a major component only if the component was also observed by the researcher to occur repeatedly across the landscape.

minor component—A map unit component composing ≤10% of the areal extent of a map unit.

conglomerate—A coarse-grained clastic sedimentary rock, composed of rounded to subangular fragments larger than 2 mm in diameter (gravels, cobble, stones, boulders) typically containing fine-grained particles (sand, silt, clay) in the interstices, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay (AGI).

constancy—A percentage of plots where a species occurs in the ecological type (Wells 2006).

convection—Transfer of heat by fluid motion between two areas with different temperatures. In meteorology, convection is the rising and descending air motion caused by heat. Atmospheric convection is almost always turbulent and is the dominant vertical transport process over tropical oceans and during sunny days over continents. The terms "convection" and "thunderstorms" are often used interchangeably, although thunderstorms are only one form of convection. In the ocean, convection is prominent in regions of high heat loss to the atmosphere and is the main mechanism for deep-water formation (NOAA).

cover—See "average cover."

country rock—(a) The preexisting rock into which a magma intrudes. (b) The pre-existing rock surrounding a pluton (Chernicoff and others 1997).

craton—A part of the Earth's crust that has attained stability and has been little deformed for a prolonged period. The term is now restricted to continental areas that have not been pervasively metamorphosed and deformed for at least about one billion years. Cratons include shield areas, where Precambrian rocks are exposed, and platform areas, where Precambrian rocks are overlain by a thin layer of Phanerozoic strata. Also spelled: kraton (AGI).

crust—The outermost layer of the Earth, consisting of relatively low-density rocks (Chernicoff et al. 1997).

cryic (soil temperature regime)—Soils in this temperature regime have a mean annual temperature lower than 8 °C but do not have permafrost (Soil Survey Staff 2003).

cryogenic solifluction—Solifluction caused by freeze-thaw processes (Davis 2001).

cuesta—An asymmetric ridge capped by resistant rock layers of slight to moderate dip, commonly less than 10º (or approximately <15% slope), produced by differential erosion of interbedded resistant and weak, easily weatherable rocks. A cuesta has a long gentle slope on one side (dipslope), that roughly parallels the inclined beds, and on the other side has a relatively short and steep or cliff-like slope (scarp) that cuts through the tilted rocks (Schoeneberger and Wysocki 2002).

D

depauperate—An unusually sparse coverage of undergrowth vegetation. This condition usually develops beneath an especially dense forest canopy, often on sites having a deep layer of duff (Wells 2006).

diabasic or diabase—similar to gabbro, but with fine-grained plagioclase crystals set in a finer matrix of pyroxene (WC).

Diameter at breast height (DBH)—Generally refers to the diameter of a tree stem at a point 1.4 m above the ground surface.

dike—An elongate, often linear igneous intrusion that cuts across the bedding or foliation of the country rock (Schoeneberger and Wysocki 2002).

diorite—A group of plutonic rocks intermediate in composition between acidic and basic, characteristically composed of dark-colored amphibole (especially hornblende), sodic plagioclase (oligoclase, andesine), pyroxene, and sometimes a small amount of quartz; also, any rock in that group; the approximate intrusive equivalent of andesite. Diorite grades into monzonite with an increase in the alkali feldspar content. In typical diorite, plagioclase contains less than 50% anorthite, hornblende predominates over pyroxene, and mafic minerals total less than 50% of the rock. Greek "diorizein," "to distinguish," in reference to the fact that the characteristic mineral, hornblende, is usually identifiable megascopically (AGI).

dip—The angle formed by the inclined plane of a geological structure and the horizontal plane of the Earth's surface (Chernicoff and others 1997).

dip-slip fault—A fault in which two sections of rock have moved apart vertically, parallel to the dip of the fault plane (Chernicoff and others 1997).

dip slope—A slope of the land surface, roughly determined by and approximately conforming with the direction and the angle of dip of the underlying rocks; specifically the long, gently inclined face of a cuesta (AGI).

disturbed or disturbance (anthropogenic)—Directly or indirectly altered, by humans, from a natural condition, yet retaining some natural characteristics (Crowe and Clausznizer 1997).

disturbed or disturbance (natural)—Any naturally occurring event (e.g., wildfire, landslide, avalanche, flood) that resets the successional dynamics of a vegetation community to an earlier state.

diversity—The number of species in a community, and their relative abundances, per unit area or volume (Wells 2006).

division—An ecological unit in the ecoregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a Domain that have the same regional climate (ECOMAP 1993).

dolomite (mineral)—A common rock-forming mineral: $CaMg(CO_3)_2$. Part of the magnesium may be replaced by ferrous iron and less frequently by manganese. Dolomite is white, colorless, or tinged yellow, brown, pink, or gray; it has a pearly to vitreous luster, and effervesces feebly in cold dilute hydrochloric acid (AGI).

dolomite (rock)—A carbonate sedimentary rock of which more than 50% by weight or by areal percentages under the microscope consists of the mineral dolomite, or a variety of limestone or marble rich in magnesium carbonate; specifically a carbonate sedimentary rock containing more than 90% dolomite and less than 10% calcite (AGI).

domain—An ecological unit in the ecoregion planning and analysis scale of the National Hierarchical Framework corresponding to subcontinental divisions of broad climatic similarity that are affected by latitude and global atmospheric conditions (ECOMAP 1993).

dominant overstory tree—A tree whose crown is positioned in the uppermost canopy layer in a forest.

E

ecological type (ET)—A category of land with a distinctive combination of landscape elements, including climate, bedrock geology, landform, and soils, and differing from other types in the kind and amount of vegetation it can produce and in its ability to respond to management actions and natural disturbances (Winthers and others 2005).

ecosystem—A complete interacting system of organisms and their environment (Wells 2006).

ecoregion—An ecological unit in the subregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a Section into areas with similar surficial geology, lithology, geomorphic process, soil groups, subregional climate, and potential natural communities (ECOMAP 1993).

ecotone—A boundary between adjacent plant communities (Crowe and Clausnitzer 1997).

edaphic—Refers to soil (Steele and others 1983).

elevation—The height of a point on the Earth's surface relative to sea level (Schoeneberger and Wysocki 2002).

eluviation—The removal of soil material in suspension (or in solution) from a layer or layers of a soil. Usually, the loss of material in solution is described by the term "leaching." See also "illuviation" (SSSA).

end moraine—A ridge-like accumulation that is being or was produced at the outer margin of an actively flowing glacier at any given time; a moraine that has been deposited at the outer or lower end of a valley glacier (Schoeneberger and Wysocki 2002).

erosion—The wearing away of the land surface by running water, waves, moving ice and wind, or by such processes as mass wasting and corrosion (Schoeneberger and Wysocki 2002).

evapotranspiration—The sum of evaporation and plant transpiration. Potential evapotranspiration is the amount of water that could be evaporated or transpired at a given temperature and humidity, if there was plenty of water available. Actual evapotranspiration cannot be any greater than precipitation, and will usually be less because some water will run off in rivers and flow to the oceans. If potential evapotranspiration is greater than actual precipitation, then soils are extremely dry during at least a major part of the year (NOAA).

extratropical—In meteorology, the area north of the Tropic of Cancer and the area south of the Tropic of Capricorn, i.e., the area outside the tropics (NOAA).

F

fan—A gently sloping, fan-shaped mass of sediment forming a low-angle cone commonly at a place where there is a notable decrease in gradient (Schoeneberger and Wysocki 2002).

fault—A fracture dividing a rock into two sections that have visibly moved relative to one another (Chernicoff and others 1997).

feldspar—Any of a group of light-colored, aluminum-silicate, rock-forming minerals most often found in plutonic igneous rocks and metamorphic rocks and often containing potassium, sodium, or calcium (Chernicoff and others 1997).

fellfield—Alpine sites characterized by relatively flat relief, very stony soils, erosion pavement, and low-growing, often widely spaced plants (Daubenmire 1978).

felsic (rock)—A rock that contains ≥70% silica, and is rich in potassium feldspar, aluminum-rich mica, and quartz (Chernicoff and others 1997).

flagged (growth form)—trees that feature short, erect stems appearing much like a flag in a stout wind, with the only living branches on the leeward side of the tree (Grant and Mitton 1977). In the study area, this growth form occurs primarily in the upper timberline.

flocculation—The coagulation of colloidal soil particles due to the ions in solution. In most soils, the clays and humic substances remain flocculated due to the presence of doubly and triply charged cations (SSSA).

fluvial—Pertaining to or produced by the action of a stream or river (Wells 2006).

floodplain—The nearly level plain that borders a stream and is subject to inundation under flood-stage conditions. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams (Schoeneberger and Wysocki 2002).

foliate—A rock showing foliation. AGI

foliation—A general term for a planar arrangement of textural or structural features in any type of rock, especially the locally planar fabric in a rock defined by a fissility, a preferred orientation of crystal planes in mineral grains, a preferred orientation of inequant grain shapes, or from compositional banding. In igneous rocks, planar parallelism of flaky or tabular minerals and mineral aggregates, slabby xenoliths, or flattened vesicles as well as compositional layering. In metamorphic rocks, planar parallelism of flaky minerals and compositional layering (AGI).

footslope—The hillslope profile position that forms the concave surface at the base of a hillslope. It is transitional between upslope sites of erosion and transport (shoulder, backslope) and downslope sites of deposition (toeslope); compare summit, shoulder, backslope, and toeslope (Schoeneberger and Wysocki 2002).

footwall—the section of rock that lies below the fault plane in a dip-slip fault (Chernicoff and others 1997).

forage—The aboveground biomass (air-dried kilograms per hectare) of all grasses, sedges, and forbs. (Wells 2006).

forb—Any herbaceous plant, usually broad leaved, that is not a graminoid (Wells 2006).

forest or forested—An area of the Earth's surface, greater than or equal to 0.04 ha, with greater than or equal to 10% cover by tree species. Does not include areas with overhanging tree limbs (Wells 2006).

foundation species—A single species that defines much of the structure of a community by creating locally stable conditions for other species, and by modulating and stabilizing fundamental ecosystem processes (Ellison and others 2005).

freeze-thaw cycle—The cyclical transition of air temperatures across 0 °C resulting in the repeated freezing and thawing of water.

frigid (soil temperature regime)—A soil with a frigid temperature regime is warmer in the summer than a soil with a cryic temperature regime, but its mean annual temperature is lower than 8 °C and the difference between mean summer (June, July, August) and mean winter (December, January, February) soil temperatures is more than 6 °C either at a depth of 50 cm from the soil surface or at a densic, lithic, or paralithic contact, whichever is shallower (Soil Survey Staff 2003).

frost-free days—The number of days during the year that the mean air temperature is greater than 0 °C. In the climate models of Zimmerman and Roberts (2000), frost-free days were calculated by simply summing the number of days that the mean annual temperature exceeded 0 °C on a pixel by pixel basis.

frost boils—bare soil patches containing mostly silt and clay that form when the fine-grained soil particles are saturated to liquefaction, or the point where the soil particles begin to behave as a liquid, and boil up through the surface due to the stress imparted by the weight of overlying soil material (Davis 2001).

frost hummocks—The product of cryoturbation. Low (typically <1 m) soil mounds that are formed from frost heaving, or the uplifting of the ground surface resulting from the freezing of water within the soil (Peterson and Krantz 2003).

G

gabbro—A group of dark-colored, basic intrusive igneous rocks composed principally of calcium-rich plagioclase and pyroxene. It is the approximate coarse-grained equivalent of basalt (AGI).

glacial—(a) [processes] Of or relating to the presence and activities of ice or glaciers, as glacial erosion, (b) [geomorphology] Pertaining to distinctive features and materials produced by or derived from glaciers and ice sheets, as glacial lakes, (c) [time period] pertaining to an ice age or region of glaciation (AGI).

glacial till—See “till.”

glacial outburst flood—A sudden, often annual release of melt-water from a glacier or glacier-damned lake sometimes resulting in a catastrophic flood, caused by a number of factors, including the melting of ice dams or drainage channels (Schoeneberger and Wysocki 2002).

glaciation—(a)The formation, movement, and recession of glaciers or ice sheets, (b) The covering of large land areas by glaciers or ice sheets (AGI).

glacier—A large mass of ice formed, at least in part, on land by compaction and recrystallization of snow, moving slowly by creep downslope or outward in all directions due to the stress of its own weight, and surviving from year to year (Schoeneberger and Wysocki 2002).

glaciofluvial deposit—Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice (Schoeneberger and Wysocki 2002).

gneiss—A coarse-grained metamorphic rock marked by bands of light-colored minerals such as quartz and feldspar that alternate with bands of dark-colored minerals (Chernicoff and others 1997).

graminoid—A grass or grasslike plant, e.g., fescue (*Festuca*), sedge (*Carex, Kobresia*), rush (*Juncus*), and woodrush (*Luzula*) species.

granite— (a) A plutonic rock in which quartz constitutes 10 to 50%of the felsic components and in which the alkali feldspar/total feldspar ratio is generally restricted to the range of 65 to 90%. (b) Broadly applied, any holocrystalline, quartz-bearing plutonic rock (AGI).

granitic—A general term used to describe granite and other silica rich igneous and metamorphic rocks, including granodiorite, quartz monzonite, gneiss, and migmatite.

granodiorite—A group of coarse-grained plutonic rocks intermediate in composition between quartz diorite and quartz monzonite (U.S. usage), containing quartz, plagioclase (oligoclase or andesine), and potassium feldspar, with biotite, hornblende, or, more rarely, pyroxene, as the mafic components; also, any member of that group. The ratio of plagioclase to total feldspar is at least 2:1 but less than 9:10. With less alkali feldspar it grades into quartz diorite, and with more alkali feldspar, into granite or quartz monzonite (AGI).

grassland—An area of the Earth’s surface, greater than or equal to 0.04 ha, with less than 10% cover by tree and shrub species, and greater than or equal to 10% cover by graminoid species.

gravel—Rock fragments greater than or equal to 2 mm and less than 75 mm in diameter (Winthers and others 2005).

greywacke—A type of poorly sorted sandstone with a mixture of quartz and feldspar grains, abundant dark rock fragments (often of volcanic origin), and fine-grained clay and mica particles (Chernicoff and others 1997).

greenschist—Metamorphosed basalt that is high in the minerals chlorite and epidote (Chernicoff and others 1997).

greenstone [meta]—A field term applied to any compact dark-green altered or metamorphosed mafic igneous rock (e.g., basalt, gabbro, diabase) that owes its color to the presence of chlorite, actinolite, or epidote (AGI).

ground moraines—(a) Commonly an extensive, low relief area of till, having an uneven or undulating surface, and commonly bounded on the distal end by a recessional or end moraine; (b) A layer of poorly sorted rock and mineral debris (till) dragged along, in, on, or beneath a glacier and deposited by processes including basal lodgement and release from downwasting stagnant ice by ablation (Schoeneberger and Wysocki 2002).

grus—The fragmental products of in situ granular disintegration of granite and granitic rocks, dominated by inter-crystal disintegration (Schoeneberger and Wysocki 2002). A type of paralithic material.

H

habitat type—All the land capable of producing similar plant communities at climax (Daubenmire 1968).

hanging wall—the section of rock that lies above the fault plane in a dip-slip fault (Chernicoff and others 1997).

headwall—A steep slope at the head of a valley; especially the rock cliff or steep rock slope at the back of a cirque (AGI).

herbaceous—Nonwoody vegetation, such as grasses and forbs (Wells 2006).

high-level erosion surface remnants—The remains of the once broad, flat erosion surface that developed during the Oligocene and early- to mid-Miocene and was subsequently uplifted and eroded as explained in Mears (1993). Examples include Horse Ridge, Goat Flat, and Ram Flat.

hornblende—The most common mineral of the amphibole group: $(Ca,Na)_{2-3}(Mg,Fe^{+2},Fe^{+3},Al)_5(OH)_2\ [(Si,Al)_8O_{22}]$. It has a variable composition, and may contain potassium and appreciable fluorine. Hornblende is commonly black, dark green, or brown, and is the primary constituent of many acid and intermediate igneous rocks (granite, syenite, diorite, andesite) and less commonly of basic igneous rocks, and it is a common metamorphic mineral in gneiss and schist (AGI).

I

ice sheet—A glacier of considerable thickness and more than 50,000 sq km in area, forming a continuous cover of ice and snow over a land surface, spreading outward in all directions and not confined by the underlying topography; a continental glacier (AGI).

igneous (rock)—A rock made from molten (melted) or partly molten material that has cooled and solidified (Chernicoff and others 1997).

illuviation—The process of deposition of soil material removed from one horizon to another in the soil; usually from an upper to a lower horizon in the soil profile. See also "eluviation" (SSSA).

indicator species—Indicator species are plants that designate thresholds of environmental change along gradients (Johnson 2004).

interglacial—Pertaining to or formed during the time interval between two successive glacial epochs or between two glacial stages. The term implies both the melting of ice sheets to about their present level, and the maintenance of a warm climate for a sufficient length of time to permit certain changes in vegetation to occur (AGI).

intrusive rock—An igneous rock formed by the entrance of magma into preexisting rock (Chernicoff and others 1997).

J

jet stream—Strong winds concentrated within a narrow zone in the atmosphere in the upper troposphere, about 9200 m aloft that generally move in an easterly direction that drive weather systems around the globe. In North America, jet streams are more pronounced in winter (NOAA).

K

kame—A low mound, knob, hummock, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margins of a melting glacier; by a supraglacial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice. (Schoeneberger and Wysocki 2002).

kettle or kettle lake—A steep-sided, bowl-shaped depression commonly without surface drainage in drift deposits, often containing a lake or swamp, and formed by the melting of a large, detached block of stagnant ice that has been wholly or partly buried in the drift. Kettle range in depth from 1 to tens of meters, and with diameters up to 13 km (Schoeneberger and Wysocki 2002).

krummholz—Trees dwarfed and twisted because of severe climate (wind, low temperature, etc.) at the high-elevation limits of forest development (Crowe and Clausnitzer 1997).

L

landform—Any physical, recognizable form or feature on the Earth's surface, having a characteristic shape and range in composition, and produced by natural causes (Schoeneberger and Wysocki 2002).

landslide—A general, encompassing term for most types of mass movement landform and processes involving the downslope transport and outward deposition of soil and rock materials, caused by gravitational forces and which may not involve saturated materials (see "solifluction") (Schoeneberger and Wysocki 2002).

late snowbank environment—A section of land surface that is influenced by snow that has been redistributed by wind and accumulated in sheltered sites, either directly by physically covering the site, or indirectly by providing melt-water throughout the growing season.

late snowbank vegetation—An assemblage of plant species occurring in a late snowbank environment. Similar in concept to snowbed communities (Douglas and Bliss 1977) or snow-patch vegetation (Helm 1982).

lateral moraine—A low ridge-like moraine carried on, or deposited at or near, the side margin of a mountain glacier. It is composed chiefly of rock fragments loosened from the valley walls by glacial abrasion and plucking, or fallen onto the ice from the bordering slopes (AGI).

lava—Magma that comes to the Earth's surface through a volcano or fissure in the Earth's crust (Chernicoff and others 1997).

leeward— refers to the direction that a slope faces (slope aspect) relative to the direction of the prevailing winds in an area. Leeward slopes are those slopes that face the same direction in which the prevailing winds blow, and are thus sheltered from the full force of those winds (see also "windward").

limestone—A sedimentary rock consisting chiefly (more than 50% by weight or by areal percentages under the microscope) of calcium carbonate, primarily in the form of the mineral calcite, and with or without magnesium carbonate; specifically a carbonate sedimentary rock containing more than 95% calcite and less than 5% dolomite (AGI).

lithic contact—The boundary between soil and a coherent underlying material, typically bedrock (Soil Survey Staff 2003).

lithic material—See "bedrock."

M

mafic (rock)—A rock having a silica content between 40% and 50%, abundant feldspar, and having high amounts of iron- and magnesium-rich minerals (Chernicoff and others 1997).

magma—Molten (melted) rock that forms naturally within the Earth (Chernicoff and others 1997).

magmatic—Pertaining to magma.

magnetite—A magnetic iron ore with the chemical composition Fe_3O_4 (Pough 1991).

mantle—The middle layer of the Earth's interior, lying just below the crust and consisting of relatively dense rock (Chernicoff and others 1997).

metagreywacke—Metamorphosed greywacke.

metamorphic (rock)—A rock that has undergone chemical or structural changes. Heat, pressure, or a chemical reaction may cause such changes (Chernicoff and others 1997).

metasedimentary (rock)—Metamorphosed sedimentary rocks.

mica—A group of minerals of general formula: (K,Na,Ca) $(Mg,Fe,Li,Al)_{2-3}(OH,F)_2[(Si,Al)_4O_{10}]$. It consists of complex phyllosilicates that crystallize in forms apparently orthorhombic or hexagonal (such as tabular six-sided prisms) but really monoclinic; that are characterized by low hardness and by perfect basal cleavage, readily splitting into thin, tough, somewhat elastic laminae or plates with a splendent pearly luster; and that range in color from colorless, silvery white, pale brown, or yellow to green or black. Micas are prominent rock-forming constituents of igneous and metamorphic rocks, and commonly occur as flakes, scales, or shreds (AGI).

microsites—Relatively small, scattered areas on a landform having environmental conditions uncharacteristic of the landform at large.

migmatite—A rock that incorporates both metamorphic and igneous materials (Chernicoff and others 1997).

mineral soil—Consist of mineral soil materials (less than 2.0 mm in diameter) (a) if the soil is saturated with water for less than 30 days (cumulative) per year in normal years, contain less than 20% (by weight) organic carbon; or (b) if the soils are saturated with water for 30 days or more cumulative in normal years and, excluding live roots, has an organic carbon content (by weight): (a) less than 18% if the mineral fraction contains 60% or more clay; (b) less than 12% if the mineral fraction contains no clay; or (c) less than 12% + (0.1*clay percentage) if the mineral fraction contains less than 60%clay (Soil Survey Staff 2003).

moist meadow—A meadow, or part of a meadow, in which the soils are not completely saturated for any part of the year; or if so, saturated for only a short period early in the growing season (Wells 2006).

moraine—(a) [material] A mound, ridge, or other topographically distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited predominantly by the direct action of glacial ice, in a variety of landforms, (b) [landform] A general term for a landform composed mainly of till that has been deposited by a glacier (Schoeneberger and Wysocki 2002).

mudstone—An indurated mud having the texture and composition of shale, but lacking its fine laminations or fissility; a blocky or massive, fine-grained sedimentary rock in which the proportions of clay and silt are approximately equal (AGI).

muscovite—The most common of a large group of sheet-structured silicate minerals having the chemical formula KAl3Si3O10(OH)2 (Pough 1991).

N

National Cooperative Soil Survey (NCSS)—A nationwide partnership of Federal, regional, state and local agencies; and private entities and institutions (USDA NRCS 2007a).

nunatak—An isolated hill, knob, ridge, or peak of bedrock that projects prominently above the surface of a glacier and is completed surrounded by glacier ice (Schoeneberger and Wysocki 2002).

O

oligoclase— A feldspar with the chemical composition Na_2Ca (Pough 1991).

organic soil—Soil material that contains more than the amounts of organic carbon described for mineral soils is considered organic soil material. Equivalent to Histosols in soil taxonomy (Soil Survey Staff 2003).

orogeny—Literally, the process of formation of mountains or a mountain building episode. By present geological usage, orogeny is the process by which structures within fold-belt mountainous areas were formed, including thrusting, folding, and faulting in the outer and higher layers, and plastic folding, metamorphism, and plutonism in the inner and deeper layers (AGI).

P

paralithic material—Relatively unaltered materials that have an extremely weakly cemented to moderately cemented rupture resistance class (e.g., grus) (Soil Survey Staff 2003).

parent material—The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of soils is developed by pedogenic processes (SSSA).

pavement or erosion pavement—A soil surface that is covered by rock fragments as the result of wind deflation, or the removal of the fine-earth fraction (<2 mm) of a soil by the force of wind (Livingstone and Warren 1996; Seppälä 2004).

ped—A unit of soil structure such as a block, column, granule, plate, or prism, formed by natural processes (in contrast with a clod, which is formed artificially) (SSSA).

pedon—A three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations (SSSA).

pedogenic—Pertaining to soil formation (AGI).

perennial—A plant that lives more than two years (Dorn 2001).

perigynium or pergynia—sheath or sac which encloses ovary and fruit in *Carex* and *Kobresia* (Dorn 2001).

piedmont—n. An area, plain, slope, glacier, or other feature at the base of a mountain. adj. Lying or formed at the base of a mountain or mountain range (AGI).

plagioclase—A feldspar with the chemical composition $(Ca,NA)AlSi_3O_8$ (Chernicoff and others 1997).

plant community—An assemblage of plants living together and interacting among themselves in a specific location (Crowe and Clausnitzer 1997).

plant community type—A set of plant communities with similar structure and floristic composition that are seral in nature and often follow directly from a disturbance event (fire, flooding, etc.). Assuming a constant environment over a given time, a plant community type will undergo a natural shift in floristic composition through plant succession (Crowe and Clausnitzer 1997).

pluton—An intrusive rock, as distinguished from the pre-existing country rock that surrounds it (Chernicoff and others 1997).

plutonic rock—Another name for intrusive rock, formed by entrance of magma into pre-existing rock (Chernicoff and others 1997).

porphyritic—Of or being an igneous rock containing some large grains within a smaller-grained matrix (Chernicoff and others 1997).

Potential Natural Vegetation (PNV)—the vegetation that would become established if all successional sequences were completed without natural disturbance or human interference under present climatic and edaphic conditions (Winthers and others 2005).

precipitation—Any form of water particles-liquid or solid-that falls from the atmosphere and reaches the ground (NOAA).

province (ecological unit classification)—An ecological unit in the ecoregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a Division that conform to climatic subzones controlled mainly by continental weather patterns (ECOMAP 1993).

province (geologic)—An extensive region characterized throughout by similar geologic history or by similar structure, petrographic, or physiographic features (AGI)

pyrogenous—See "serotinous."

pyroxene—A large group of rock-forming calcium, iron, magnesium, and aluminum silicates. Pyroxenes are similar to amphiboles, but contain no water (Pough 1991).

Q

quartz—Crystalline silica, an important rock-forming mineral: SiO^2. It is, next to feldspar, the commonest mineral (AGI).

quartz diorite—A group of plutonic rocks having the composition of diorite but with an appreciable amount of quartz, i.e., between 5 and 20% of the light-colored constituents. Quartz diorite grades into granodiorite as the alkali feldspar content increases (AGI).

quartz monzonite—In former U.S. usage, granitic rock in which quartz comprises 10–50% of the felsic constituents, and in which the alkali feldspar/total feldspar ratio is between 35% and 65%. With an increase in plagioclase and femic minerals, it grades into granodiorite and with more alkali feldspar, into a granite. Now the term is applied by most British petrologists to granites with quartz constituting 20–60% of the light-colored components and with a plagioclase/total feldspar ratio of 35/65 (AGI).

R

rainshadow—The region on the leeside of a mountain where the precipitation is noticeable less than on the windward side (NOAA).

recessional moraine—An end or lateral moraine built during a temporary but significant pause in the final retreat of a glacier. Also, a moraine built during a slight or minor re-advance of the ice front during a period of general recession (AGI).

redoximorphic concentrations—Pore linings, soft masses, nodules, concretions, and other features resulting from the accumulation of iron or manganese oxide. An indication of chemical reduction and oxidation resulting from saturation (Soil Survey Staff 2003).

redoximorphic depletions—Low-chroma zones from which iron and manganese oxide or a combination of iron and manganese oxide and clay has been removed. These zones are indications of the chemical reduction of iron resulting from saturation (Soil Survey Staff 2003).

redoximorphic features—Redoximorphic concentrations, redoximorphic depletions, reduced matrices, and other features indicating the chemical reduction and oxidation of iron and manganese compounds resulting from saturation (SSSA).

reduced matrix—A soil matrix that has low chroma in situ because of chemically reduced iron (Fe II). The chemical reduction results from nearly continuous wetness. The matrix undergoes a change in hue or chroma within 30 minutes after exposure to air as the iron is oxidized (Fe III) (SSSA).

regolith—All unconsolidated earth materials above the solid bedrock. It includes material weathered in place from all kinds of bedrock and alluvial, glacial, eolian, lacustrine, and pyroclastic deposits. Soil scientists regard as soil only that part of the regolith that is modified by organisms and soil forming processes. Most engineers describe the whole regolith, even to a great depth, as "soil" (Schoeneberger and Wysocki 2002).

residuum—Unconsolidated, weathered, or partly weathered mineral material that accumulates by disintegration of bedrock in place (Schoeneberger and Wysocki 2002).

residual—Referring to a soil formed from residuum.

reverse fault—A dip-slip fault marked by a hanging wall that has moved upward relative to the footwall (Chernicoff and others 1997).

rhizome—Underground stem or rarely creeping along ground surface (Dorn 2001).

rhizomatous—With rhizomes (Dorn 2001).

riparian zone (ecosystem)—Riparian zones are defined as the strip of land along streams or rivers that is affected by stream processes (flooding, sedimentation, etc.) and that, in turn, affects stream structure and function (Wells, 2006).

rock fragments—Any pieces of rock larger than 2 mm located in a soil profile including gravels (2 to 75 mm), cobbles (75 to 250 mm), stones (250 to 600 mm), and boulders (>600 mm).

S

sand—Soil particles between 0.05 mm and 0.002 mm in diameter, see also "soil separates." As a textural class, soil material that contains 85% or more of sand; percentage of silt, plus 1.5 times the percentage of clay, shall not exceed 15% (SSSA).

sandy-shale—A sedimentary rock intermediate between sandstone and shale that is typically composed of thin layers of fine-grained sand held together by a cementing agent, such as calcium carbonate or silica.

sandstone—A medium-grained clastic sedimentary rock composed of abundant rounded or angular fragments of sand size with or without a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material (commonly silica, iron oxide, or calcium carbonate) (AGI).

scarp slope—The relatively steeper face of a cuesta, facing in a direction opposite to the dip of the strata (Schoeneberger and Wysocki 2002).

schist—A strongly foliated crystalline rock, formed by dynamic metamorphism, that can be readily split into thin flakes or slabs because of the well-developed parallelism of more than 50% of the minerals present, particularly those of lamellar or elongate prismatic habit (e.g., mica and hornblende) (AGI).

section—An ecological unit in the subregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a Province having broad areas of similar geomorphic process, stratigraphy, geologic origin, drainage networks, topography, and regional climate. Such areas are often inferred by relating geologic maps to Kuchler (1964) potential natural vegetation groupings (ECOMAP 1993).

sediment—Material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by water, wind, ice or mass-wasting and has come to rest on the Earth's surface either above or below sea level (Schoeneberger and Wysocki 2002).

sedimentary (rock)—A consolidated deposit of clastic particles, chemical precipitates, or organic remains accumulated at or near the surface of the earth under "normal" low temperature and pressure conditions. Sedimentary rocks include consolidated equivalents of alluvium, colluvium, drift, and eolian, lacustrine, marine deposits; e.g., sandstone, siltstone, mudstone, clay-stone, shale, conglomerate, limestone, dolomite, coal, etc. (USDA NRCS 2002a).

seep—An area, generally small, where water percolates slowly to the ground surface. For water, it may be considered as a seepage spring, but it is used in some cases for flows too small to be considered as springs (Schoeneberger and Wysocki 2002).

seral—(a) Vegetation—Refers to species, communities, or stands whose presence is due to disturbance, and in the absence of disturbance are eventually replaced with potential natural vegetation; (b) Stage—Refers to unique, recognizable assemblages of seral vegetation that represent the progression from the time period immediately following a disturbance event to the establishment of potential natural vegetation.

serotinous or serotiny—Used in relation to pine cones that require high temperatures to open and release seeds, particularly in lodgepole pine (Anderson 2003).

shale—A laminated, indurated rock with >67% clay-sized minerals; a claystone with fissility (AGI).

shoulder—The hill slope profile position that forms the convex, erosional surface near the top of a slope. If present, it comprises the transition between summit and backslope; compare summit, backslope, footslope, and toeslope (Schoeneberger and Wysocki 2002).

shrub—A woody plant that at maturity is usually less than 6 m tall and generally exhibits several erect, spreading, or prostrate stems and has a bushy appearance; e.g., mountain big sagebrush or planeleaf willow.

shrubland—An area of the Earth's surface, greater than or equal to 0.04 ha, with less than 10% cover by tree species, and greater than or equal to 10% cover by shrub species.

silt—Soil particles between 0.05 mm and 0.002 mm in diameter, see also "soil separates." As a textural class, soil material that contains 80% or more silt-sized soil particles and less than 12% clay-sized particles (SSSA).

siltstone—An indurated silt having the texture and composition of shale but lacking its fine lamination or fissility; a massive mudstone in which the silt predominates over clay (AGI).

site water balance (SWB)—The difference between evapotranspiration and precipitation.

slope or slope gradient—The angle of the ground surface (in percent) through the site and in the direction that overland water would flow (Schoeneberger and others 2002).

snow—Solid precipitation in the form of minute ice flakes that occur below 0 °C (NOAA).

snowpack—A horizontally layered accumulation of snow from snowfall events, which may be modified by meteorological conditions over time (NOAA).

soil—A natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment (Soil Survey Staff 2003).

soil map unit—A National Cooperative Soil Survey land unit classification concept that refers to a collection of areas defined and named the same in terms of their soil components and vegetation (Soil Survey Division Staff 1993).

soil separates—Mineral particles, <2.0 mm in equivalent diameter, ranging between specified size limits. The names and size limits of separates recognized in the USA are: very coarse sand, 2.0 to 1.0 mm; coarse sand, 1.0 to 0.5 mm; medium sand, 0.5 to 0.25 mm; fine sand, 0.25 to 0.10 mm; very fine sand, 0.10 to 0.05 mm; silt, 0.05 to 0.002 mm; and clay, <0.002 mm. The separates recognized by the International Society of Soil Science are: (i) coarse sand, 2.0 to 0.2 mm; (ii) fine sand, 0.2 to 0.02 mm; (iii) silt, 0.02 to 0.002 mm; and (iv) clay, <0.002 mm (SSSA).

soil moisture control section—The intent of the soil moisture control section is to facilitate estimation of soil moisture regimes from climatic data. The upper boundary of this control section is the depth to which a dry soil will be moistened by 2.5 cm of water within 48 hours. The lower boundary is the depth to which a soil will be moistened by 7.5 cm of water within 48 hours (Soil Survey Staff 2003).

soil moisture regime (SMR)—A soil taxonomy concept that refers to the presence or absence of ground water, or the amount of water in a given soil that is available to plants (Soil Survey Staff 2003).

soil temperature regime (STR)—A soil taxonomy concept that refers to the range of temperatures a soil experiences annually.

solar radiation—Energy received from the sun is solar radiation. The energy comes in many forms, such as visible light (that which we can see with our eyes). Other forms of radiation include radio waves, heat (infrared), ultraviolet waves, and x-rays. These forms are categorized within the electromagnetic spectrum (NOAA).

solifluction—The slow, viscous downslope flow of water-saturated regolith. Rates of flow vary widely. The presence of frozen substrate or even freezing and thawing is not implied in the original definition. However, one component of solifluction can be creep or frozen ground (see "cryogenic solifluction"). The term is commonly applied to processes operating in both seasonal frost and permafrost areas (Schoeneberger and others 2002).

solifluction lobe—Solifluction lobes are narrow, linear landforms resulting from the accumulation of soils due to solifluction that tend to develop on steeper slopes (Davis 2001).

solifluction terrace—broad, bench-like landforms resulting from the accumulation of soils due to solifluction that tend to develop on shallower slopes (Davis 2001).

solum—A set of soil horizons that are related through the same cycle of pedogenic processes; the A, E, and B horizons (SSSA).

spire (growth form)—typical tree growth form with a central stem, and radiating branches (Grant and Mitton 1977).

spring—An area where groundwater flows onto the Earth's surface (Crowe and Clausnitzer 1997).

stand—An existing plant community that is relatively uniform in composition, structure, and site conditions; thus, it may serve as a local example of a community type or habitat type (Wells 2006).

stolon—An elongate, creeping stem on the surface of the ground (Wells 2006).

stoloniferous—Bearing stolons (Wells 2006).

stone—Rock fragments greater than or equal to 250 mm and less than 600 mm in diameter (Winthers and others 2005).

stone nets—A type of sorted ground and the product of cryoturbation. Stone nets occur on flat or gentle slopes (<7%), and feature a series of rock polygons, or "cells" of the "net," interlaced with a net-like pattern of smaller rock fragments and soil material (Richmond, 1949). Stone nets are not only formed from stone in the technical sense (see "stone"), but rock fragments, including gravels, cobbles, stones, and boulders.

stone stripes—A type of sorted ground and the product of cryoturbation. The linear equivalent of stone nets that occurs on steeper slope gradients typically between 7% and 27% (Richmond 1949).

subsection—see "ecoregion."

succession—The progressive changes in plant communities toward a steady state. Primary succession begins on a bare surface not previously occupied by plants, such as a recently deposited gravel bar. Secondary succession occurs following disturbances on sites that previously supported vegetation.

subdominant overstory tree—A tree whose crown is positioned slightly below the uppermost canopy layer of a forest.

summit—(a) The topographically highest position of a hill slope profile with a nearly level planar or slightly convex surface, compare — shoulder, backslope, footslope, toeslope; (b) A general term for the top, or highest area of a landform such as a hill, mountain, or tableland. It usually refers to a high interfluve area of relatively gentle slope that is flanked by steeper slopes (Schoeneberger and Wysocki 2002).

survey order—Levels of a soil survey that differ in the intensity of the field study, degree of detail in mapping, degree of abstraction in defining and naming map units, and map unit design (Soil Survey Division Staff 1993). There are five soil survey orders:

1st order—Very intensive, appropriate scales for field mapping and publication are 1:15,840 or larger.

2nd order—Intensive, appropriate scales for field mapping and publication are 1:12,000 to 1:31,680.

3rd order—Extensive, appropriate scales for field mapping and publication are 1:20,000 to 1:63,360.

4th order—Extensive, appropriate scales for field mapping and publication are 1:63,360 to 1:250,000.

5th order—Very extensive, appropriate scales for field mapping and publication are 1:250,000 to 1:1,000,000.

T

talus—Rock fragments of any size or shape (usually coarse or angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding (Schoeneberger and Wysocki 2002).

tectonic—Pertaining to movements and deformation of the Earth's crust.

terrace or stream terrace—One or a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the remnants of an abandoned floodplain, streambed, or valley floor produced during a former state of fluvial erosion or deposition (i.e., currently very rarely or never floods, inactive cut and fill or scour and fill processes) (Schoeneberger and Wysocki 2002).

terrane—A fault-bounded body of rock of regional extent, characterized by a geologic history different from that of contiguous terranes or bounding continents. A terrane is generally considered to be a discrete allochthonous fragment of oceanic or continental material added to a craton at an active margin by accretion (AGI).

terrestrial ecological unit inventory (TEUI)—Ecological type approach to land classification developed by the U.S. Forest Service. TEUI is a field sampling protocol and ecological type classification system, the purpose of which is to collect information on the nature and distribution of ecosystems, and to classify ecosystem types and map land areas with similar capabilities and potential for management (Winthers and others 2005).

thrust fault—A reverse fault marked by a dip of 45º or less (Chernicoff and others 1997).

till—Dominantly unsorted and unstratified drift, generally unconsolidated and deposited directly by a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders (Schoeneberger and Wysocki 2002).

timberline—(a)The elevational region, identifical by characteristic vegetation, between the subalpine and alpine zones. The boundaries between these zones vary considerably from one geographical region to another and with microclimatic conditions; (b) The relatively narrow elevation zone representing the upper limits of erect tree growth.

toeslope—The hillslope position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear, and are constructional surfaces forming in the lower part of a hill slope continuum that grades to valley floors or the topographical bottom of closed basins; compare summit, shoulder, backslope, and footslope (Schoeneberger and Wysocki 2002).

topoedaphic—Refers to a combination of topography and soils (Steele and others 1983).

topography—The relative positions and elevations of the natural or manmade features of an area that describe the configuration of its surface (Schoeneberger and Wysocki 2002).

tree—A woody plant that at maturity is usually 6 m or more in height and generally has a single trunk unbranched to about 1 m above the ground and a more or less definite crown (Wells 2006).

treeline (lower)—The lower elevation limits of tree growth.

treeline (upper)—see "timberline."

tree islands—Scattered patches of forested vegetation separated from one another by sections of alpine meadow (Marr 1977). Tree islands occur mostly near timberline.

trellis drainage pattern—A drainage pattern characterized by parallel main streams intersected at, or nearly at, right angles by their tributaries, which in turn are fed by elongate secondary tributaries and short gullies parallel to the main streams, resembling in plan view, the stems of a vine on a trellis. This pattern indicates marked bedrock structural control rather than a type of bedrock (Schoeneberger and Wysocki 2002).

tuff—Consolidated or cemented volcanic ash and lapilli (AGI).

turf—See "alpine turf."

U

udic (soil moisture regime)—A soil moisture regime in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years (Soil Survey Staff 2003).

ultramafic (rock)—A dark-colored rock dominated by the iron- and magnesium-containing minerals olivine and pyroxene, and having less than 40% silica (Chernicoff and others 1997).

understory tree—A tree with a diameter at breast height less than 13 cm.

upland—Land at a higher elevation than the floodplain or lowest stream terrace (Schoeneberger and Wysocki 2002).

ustic (soil moisture regime)—A soil in which moisture is limited but is present at a time when conditions are suitable for plant growth (Soil Survey Staff 2003).

V

valley—An elongate, relatively large, externally drained depression of the Earth's surface (Wells 2006).

valley floor—The comparatively broad, flat bottom of a valley; it may be excavated and represent the level of a former erosion cycle, or it may be buried under a thin cover of alluvium (Schoeneberger and Wysocki 2002).

vegetation type—A general term referring to habitat type, plant community types, and plant communities.

W

water table—The depth beneath the soil surface below which the ground is saturated with water. The depth to standing water (Crowe and Clausnitzer 1997).

weathering—All physical and chemical changes produced in rocks or other deposits at or near the Earth's surface by atmospheric agents with essentially no transport of the altered material. These changes result in disintegration and decomposition of the material (Wells 2006).

wetland—Lands within or adjacent to, and hydrologically influenced by, streams, rivers, lakes, meadows, and seeps (Cowardin and others 1979).

wildfire—Any fire that occurs in an ecosystem that started by natural means, e.g., lighting strike.

windward—refers to the direction that a slope faces (slope aspect) relative to the direction of the prevailing winds in an area. Windward slopes are those slopes that face the opposite direction in which the prevailing winds blow, and are thus exposed to the full force of those winds (see also "leeward").

Appendix 1: SNOTEL Precipitation and Temperature Data Summaries

Table 1-1. SNOTEL precipitation and temperature data summaries for the South Pass station, Wind River Range, Shoshone National Forest, WY, 1986-2006.

Name: South Pass
Site Number: 775
Station ID: 08g03s
Elevation: 2756 m

Latitude: 42° 34’
Longitude: -108° 50’
Timeframe: 1986-2006

Month	Temperature (Degrees C)						Precipitation (cm)				
				2 years in 10 will have		avg. # total degree days per month[a]	avg. total monthly precip	2 years in 10, total monthly precip will be		Snow water equivalent (accumulated)	
	avg. daily max	avg. daily min	avg.	max temp >than	min temp <than			less than	more than	avg. 1st of month	avg. 15th of month
January	0.4	-13.6	-7.7	5	-19	0	7.1	4.6	9.4	19.8	23.4
February	1.5	-13.8	-7.4	6	-19	0	6.6	3.0	8.4	26.9	30.2
March	4.7	-11.1	-4.2	9	-16	0	7.6	5.3	10.9	34.3	37.8
April	8.3	-7.0	-0.2	13	-12	19	9.1	5.6	11.2	41.7	42.2
May	11.9	-2.2	4.1	17	-5	151	7.6	5.1	9.7	40.6	30.5
June	17.5	2.1	9.2	23	-1	294	4.8	1.5	7.4	11.2	4.6
July	22.7	5.8	13.5	26	3	443	2.5	0.3	4.3	0.0	0.0
August	21.7	5.4	12.6	25	3	421	3.0	1.3	4.8	0.0	0.0
September	15.9	1.1	7.5	21	-2	255	4.1	1.8	6.4	0.0	0.0
October	9.7	-3.7	2.0	15	-7	94	5.3	3.8	8.4	0.3	0.8
November	2.4	-10.5	-5.0	8	-16	0	7.9	4.3	10.2	3.8	7.1
December	-0.4	-13.7	-8.2	5	-19	0	7.6	4.3	9.9	11.2	15.7
Annual											
Average	9.8	-5.1	1.4	14	-9						
Extreme	31.9	-38.6									
Total						1677	73.4	40.9	100.8		

[a] Refers to growing degree days, a unit of heat available for plant growth. It can be calculated on a daily basis by adding the minimum and maximum daily temperatures, and dividing the sum by 2.

Table 1-2. SNOTEL precipitation and temperature data summaries for the Townsend Creek station, Wind River Range, Shoshone National Forest, WY, 1990-2006.

Name: Townsend Creek
Site Number: 826
Station ID: 08g07s
Elevation: 2652 m

Latitude: 42° 41’
Longitude: -108° 53’
Timeframe: 1990-2006

	Temperature (Degrees C)						Precipitation (cm)				
				2 years in 10 will have		avg. # total degree days per month[a]	avg. total monthly precip	2 years in 10, total monthly precip will be		Snow water equivalent (accumulated)	
Month	avg. daily max	avg. daily min	avg.	max temp >than	min temp <than			less than	more than	avg. 1st of month	avg. 15th of month
January	1.0	-14.7	-6.9	5	-21	0	3.6	2.5	5.1	10.9	12.7
February	2.1	-15.5	-7.0	7	-22	0	4.3	2.0	6.4	14.2	16.3
March	5.1	-12.2	-3.7	10	-19	0	6.1	3.6	7.9	18.3	20.6
April	7.9	-7.5	0.2	13	-13	7	8.9	4.3	12.7	23.6	23.4
May	12.6	-2.7	4.9	18	-6	153	7.6	4.8	10.9	19.3	10.9
June	17.8	0.9	9.6	23	-2	280	5.3	1.5	8.9	2.5	0.8
July	23.1	4.0	13.7	26	1	421	2.8	1.3	4.3	0.0	0.0
August	22.5	3.9	13.0	25	2	409	3.3	2.0	3.8	0.0	0.0
September	16.8	-0.2	7.8	22	-3	249	4.8	3.0	6.1	0.0	0.0
October	10.4	-4.7	2.2	16	-8	87	5.8	2.8	8.1	0.3	0.5
November	3.6	-11.9	-4.3	9	-19	0	5.3	2.8	7.4	2.8	4.8
December	0.4	-15.1	-7.5	5	-21	0	3.6	1.8	5.1	7.1	8.9
Annual											
Average	10.3	-6.3	1.9	15	-11						
Extreme	32.6	-40.0									
Total						1606	61.5	32.5	86.6		

[a] Refers to growing degree days, a unit of heat available for plant growth. It can be calculated on a daily basis by adding the minimum and maximum daily temperatures, and dividing the sum by 2.

Table 1-3. SNOTEL precipitation and temperature data summaries for the Hobbs Park station, Wind River Range, Shoshone National Forest, WY, 1990-2006.

Name: Hobbs Park
Site Number: 525
Station ID: 09g03s
Elevation: 3079 m

Latitude: 42° 52’
Longitude: -109° 5’
Timeframe: 1990-2006

	Temperature (Degrees C)						Precipitation (cm)				
				2 years in 10 will have		avg. # total degree days per month[a]	avg. total monthly precip	2 years in 10, total monthly precip will be		Snow water equivalent (accumulated)	
Month	avg. daily max	avg. daily min	avg.	max temp >than	min temp <than			less than	more than	avg. 1st of month	avg. 15th of month
January	-2.3	-14.0	-7.8	2	-20	0	4.3	3.0	5.3	17.5	20.3
February	-0.9	-14.5	-7.8	4	-20	0	4.8	2.8	5.8	22.9	25.4
March	2.0	-12.2	-5.3	6	-18	0	6.9	4.3	8.6	28.7	32.3
April	5.3	-8.7	-1.9	10	-14	0	9.9	6.1	14.5	36.1	38.6
May	9.5	-3.6	2.8	14	-7	91	9.4	6.1	12.2	40.9	36.1
June	14.0	0.5	7.4	18	-2	217	6.1	2.3	10.7	18.3	8.6
July	19.0	4.4	11.8	22	1	364	3.8	1.8	5.3	1.5	0.0
August	18.5	4.2	11.3	21	2	353	3.6	2.3	4.8	0.0	0.0
September	13.3	0.0	6.4	18	-3	200	4.3	2.5	6.9	0.0	0.0
October	7.3	-4.9	1.0	12	-9	38	5.8	2.5	8.4	0.5	1.8
November	0.6	-11.3	-5.3	6	-18	0	5.6	3.6	6.9	5.8	8.6
December	-2.5	-14.0	-8.1	2	-20	0	4.3	2.8	5.6	12.2	15.0
Annual											
Average	7.0	-6.1	0.4	11	-11						
Extreme	27.1	-37.2									
Total						1263	68.8	40.1	95.0		

[a] Refers to growing degree days, a unit of heat available for plant growth. It can be calculated on a daily basis by adding the minimum and maximum daily temperatures, and dividing the sum by 2.

Table 1-4. SNOTEL precipitation and temperature data summaries for the Cold Springs station, Wind River Range, Shoshone National Forest, WY, 1990-2006.

Name: Cold Springs
Site Number: 405
Station ID: 09f25s
Elevation: 2935 m

Latitude: 43° 16’
Longitude: -109° 26’
Timeframe:1990-2006

Month	Temperature (Degrees C)						Precipitation (cm)				
				2 years in 10 will have		avg. # total degree days per month[a]	avg. total monthly precip	2 years in 10, total monthly precip will be		Snow water equivalent (accumulated)	
	avg. daily max	avg. daily min	avg.	max temp >than	min temp <than			less than	more than	avg. 1st of month	avg. 15th of month
January	-1.7	-11.9	-7.1	3	-17	0	3.3	2.3	4.1	9.4	10.9
February	-0.5	-12.6	-7.1	4	-18	0	3.6	1.8	4.6	12.2	13.7
March	2.7	-10.4	-4.5	7	-15	0	4.8	3.6	6.4	15.5	17.3
April	5.8	-7.1	-1.3	10	-12	0	7.4	3.8	10.7	18.8	15.2
May	10.2	-2.4	3.2	15	-6	120	7.4	4.6	10.2	10.2	7.1
June	15.0	1.7	7.8	20	-1	251	5.3	1.3	10.9	2.5	0.5
July	20.4	5.8	12.4	24	3	405	3.3	1.3	4.8	0.0	0.0
August	19.9	5.5	11.8	23	3	394	3.3	2.0	4.8	0.0	0.0
September	14.4	1.4	7.0	19	-2	237	4.1	2.5	5.3	0.0	0.0
October	8.3	-3.6	1.6	14	-8	73	4.6	2.3	6.4	0.0	0.3
November	1.2	-9.5	-4.5	7	-15	0	4.8	3.3	6.9	2.0	4.1
December	-2.2	-12.1	-7.3	3	-17	0	3.3	1.3	4.3	6.4	7.6
Annual											
Average	7.8	-4.6	1.0	12	-9						
Extreme	29.3	-37.5									
Total						1480	55.1	30.0	79.2		

[a] Refers to growing degree days, a unit of heat available for plant growth. It can be calculated on a daily basis by adding the minimum and maximum daily temperatures, and dividing the sum by 2.

Appendix 2: Total Species List

A listing of all plant taxa encountered during field sampling, including USDA code (USDA Plants Code [USDA, NRCS 2007b]), Lifeform (LF), common name, scientific name, and author (author epithet, including species epithet and variety epithet, when available, seperated by a semi-colon).

Appendix 2. Total species list sorted in alphabetical order by USDA Plants Code.

USDA code	LF	Common name	Scientific name	Author
Trees				
ABLA	T	subalpine fir	*Abies lasiocarpa*	(Hook.) Nutt.
JUSC2	T	Rocky Mountain juniper	*Juniperus scopulorum*	Sarg.
PIAL	T	whitebark pine	*Pinus albicaulis*	Engelm.
PICOL	T	lodgepole pine	*Pinus contorta* var. *latifolia*	Dougl. ex Loud.; Engelm. ex S. Wats.
PIEN	T	Engelmann spruce	*Picea engelmannii*	Parry ex Engelm.
PIFL2	T	limber pine	*Pinus flexilis*	James
POTR5	T	quaking aspen	*Populus tremuloides*	Michx.
PSMEG	T	Rocky Mountain Douglas-fir	*Pseudotsuga menziesii* var. *glauca*	(Mirbel) Franco; (Beissn.) Franco
Shrubs				
ACGL	S	Rocky Mountain maple	*Acer glabrum*	Torr.
ALVIS2	S	Sitka alder	*Alnus viridis* var. *sinuata*	(Chaix) DC.; Regel
AMAL2	S	western serviceberry	*Amelanchier alnifolia*	Nutt.
ARAR8	S	low sagebrush	*Artemisia arbuscula*	Nutt.
ARCA13	S	silver sagebrush	*Artemisia cana*	Pursh
ARFR4	S	fringed sagewort	*Artemisia frigida*	Willd.
ARTRR4	S	Wyoming three-tip sagebrush	*Artemisia tripartita* var. *rupicola*	Rydb. (Beetle) Dorn
ARTRV2	S	mountain big sagebrush	*Artemisia tridentata* var. *vaseyana*	Nutt.; (Rydb.) Boivin
ARUV	S	kinnikinnick	*Arctostaphylos uva-ursi*	(L.) Spreng.
BEGL	S	bog birch	*Betula glandulosa*	Michx.
CEVE	S	snowbrush ceanothus	*Ceanothus velutinus*	Dougl. ex Hook.
CHUMO	S	pipsissewa	*Chimaphila umbellata* var. *occidentalis*	(L.) W. Bart.; (Rydb.) Blake
CHVI8	S	yellow rabbitbrush	*Chrysothamnus viscidiflorus*	(Hook.) Nutt.
COSE16	S	red-osier dogwood	*Cornus sericea*	L.

USDA code	LF	Common name	Scientific name	Author
DROCH3	S	Hooker's mountain avens	*Dryas octopetala* var. *hookeriana*	L.; (Juz.) Breitung
ERNAN5	S	rubber rabbitbrush	*Ericameria nauseosa* var. *nauseosa*	(Pallas ex Pursh) Nesom & Baird
HODU	S	rockspirea	*Holodiscus dumosus*	(Nutt. ex Hook.) Heller
JUCOD	S	common juniper	*Juniperus communis* var. *depressa*	L.
JUOS	S	Utah juniper	*Juniperus osteospema*	(Torr.) Little
KAMI	S	alpine laurel	*Kalmia microphylla*	(Hook.) Heller
LOIN5	S	twinberry honeysuckle	*Lonicera involucrata*	Banks ex Spreng.
MARE11	S	Oregon grape	*Mahonia repens*	(Lindl.) G. Don
PAMY	S	Oregon boxleaf	*Paxistima myrsinites*	(Pursh) Raf.
PEFL15	S	shrubby cinquefoil	*Pentaphylloides floribunda*	(Pursh) Love
PHEM	S	pink mountainheath	*Phyllodoce empetriformis*	(Sw.) D. Don
PRVIM	S	black chokecherry	*Prunus virginiana* var. *melanocarpa*	L.; (A. Nels.) Sarg.
PUTR2	S	antelope bitterbrush	*Purshia tridentata*	(Pursh) DC.
RHART2	S	skunkbush sumac	*Rhus aromatica* var. *trilobata*	Ait.; (Nutt.) Gray ex. S. Wats.
RIBES	S	currant	*Ribes*	L.
RICEP	S	whisky currant	*Ribes cereum* var. *pedicellare*	Dougl.; Brewer & S. Wats.
RIHU	S	northern black currant	*Ribes hudsonianum*	Richards.
RILA	S	prickly currant	*Ribes lacustre*	(Pers.) Poir.
RIMO2	S	gooseberry currant	*Ribes montigenum*	McClatchie
RIOX	S	Canadian gooseberry	*Ribes oxyacanthoides*	L.
RIVI3	S	sticky currant	*Ribes viscosissimum*	Pursh
ROSA3	S	prickly rose	*Rosa sayi*	Schwein.
ROWO	S	woods rose	*Rosa woodsii*	Lindl.
RUID	S	grayleaf red raspberry	*Rubus idaeus*	L.
SAARP5	S	arctic willow	*Salix arctica* var. *petraea*	Pallas; (Anderss.) Bebb
SABR	S	short-fruit willow	*Salix brachycarpa*	Nutt.
SACA6	S	cascade willow	*Salix cascadensis*	Cockerell
SACE3	S	blue elderberry	*Sambucus cerulea*	Raf.
SADR	S	Drummond's willow	*Salix drummondiana*	Barratt
SAER	S	Missouri River willow	*Salix eriocephala*	Michx.
SAEX	S	sandbar willow	*Salix exigua*	Nutt.
SAFA	S	farr's willow	*Salix farriae*	Ball
SAGE2	S	Geyer willow	*Salix geyeriana*	Anderss.
SAGLV	S	grayleaf willow	*Salix glauca* var. *villosa*	L.; Anderss.
SAMBU	S	elderberry	*Sambucus*	L.
SAPL2	S	planeleaf willow	*Salix planifolia*	Pursh
SARA2	S	red elderberry	*Sambucus racemosa*	L.
SAREN2	S	snow willow	*Salix reticulata* var. *nana*	L.; (Hook.) Anderss.

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SASC	S	Scouler's willow	*Salix scouleriana*	Barratt ex Hook.
SATW	S	Tweedy's willow	*Salix tweedyi*	(Bebb ex Rose) Ball
SAWO	S	Wolf's willow	*Salix wolfii*	Bebb
SHCA	S	russet buffaloberry	*Shepherdia canadensis*	(L.) Nutt.
SYORU	S	Utah snowberry	*Symphoricarpos oreophilus* var. *utahensis*	Gray; (Rydb.) A. Nels.
VACE	S	dwarf bilberry	*Vaccinium cespitosum*	Michx.
VAOC	S	bog blueberry	*Vaccinium occidentale*	Gray
VASC	S	grouse whortleberry	*Vaccinium scoparium*	Leiberg
Forbs				
ACCO4	F	monkshood	*Aconitum columbianum*	Nutt.
ACMIL3	F	western yarrow	*Achillea millefolium* var. *lanulosa*	DC. ; (Nutt.) Piper
ACRU2	F	baneberry	*Actaea rubra*	(Ait.) Willd.
AGGL	F	pale agoseris	*Agoseris glauca*	(Pursh) Raf.
AGOSE	F	agoseris	*Agoseris*	Raf.
ALAL3	F	pale madwort	*Alyssum alyssoides*	L.
ALCE2	F	nodding onion	*Allium cernuum*	Roth
ALDE	F	desert alyssum	*Alyssum desertorum*	Stapf
ALSC	F	wild chives	*Allium schoenoprasum*	L.
ALTE	F	textile onion	*Allium textile*	Nels. & Macbr.
ANAN2	F	tall pussy-toes	*Antennaria anaphaloides*	Rydb.
ANCO	F	meadow pussy-toes	*Antennaria corymbosa*	E. Nels.
ANEMO	F	anemone	*Anemone*	L.
ANMA	F	common pearly-everlasting	*Anaphalis margaritacea*	(L.) B. & H.
ANME2	F	Rocky Mountain pussytoes	*Antennaria media*	Greene
ANMI3	F	littleleaf pussytoes	*Antennaria microphylla*	Rydb.
ANPAM	F	cutleaf anemone	*Anemone patens* var. *multifida*	L.; Pritz.
ANRA	F	raceme pussy-toes	*Antennaria racemosa*	Hook.
ANRO2	F	rosy pussy-toes	*Antennaria rosea*	Greene
ANSES	F	pygmyflower rockjasmine	*Androsace septentrionalis* var. *subulifera*	L.; Gray
ANTEN	F	everlasting; pussy-toes	*Antennaria*	Gaertn.
ANUM	F	umber pussy-toes	*Antennaria umbrinella*	Rydb.
APAN2	F	spreading dogbane	*Apocynum androsaemifolium*	L.
AQCO	F	Colorado blue columbine	*Aquilegia coerulea*	James
ARCO9	F	heartleaf arnica	*Arnica cordifolia*	Hook.
ARENA	F	sandwort	*Arenaria*	L.
ARFU3	F	orange arnica	*Arnica fulgens*	Pursh

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ARHI	F	hairy rockcress	*Arabis hirsuta*	(L.) Scop.
ARLA8	F	broadleaf arnica	*Arnica latifolia*	Bong.
ARLU	F	white sagebrush	*Artemisia ludoviciana*	Nutt.
ARMO4	F	hairy arnica	*Arnica mollis*	Hook.
ARRY	F	rydberg's arnica	*Arnica rydbergii*	Greene
ARSC	F	alpine sagebrush	*Artemisia scopulorum*	Gray
ASAG2	F	field milkvetch	*Astragalus agrestis*	Dougl. ex G. Don
ASAL7	F	alpine milkvetch	*Astragalus alpinus*	L.
ASAUG	F	Indian milkvetch	*Astragalus australis* var. *glabriusculus*	(L.) Lam.; (Hook.) Isely
ASEU2	F	pretty milkvetch	*Astragalus eucosmus*	B.L. Robins.
ASKE	F	spiny milkvetch	*Astragalus kentrophyta*	Gray
ASMI9	F	timber milkvetch	*Astragalus miser*	Dougl.
ASTER	F	aster	*Aster*	L.
ASTRA	F	milkvetch; orophaca	*Astragalus*	L.
BAIN	F	hoary balsamroot	*Balsamorhiza incana*	Nutt.
BASA3	F	arrowleaf balsamroot	*Balsamorhiza sagittata*	(Pursh) Nutt.
BEWY	F	wyoming kittentail	*Besseya wyomingensis*	(A. Nels.) Rydb.
BOAN6	F	Drummond's rockcress	*Boechera angustifolia*	(Nutt.) Dorn
BOBR4	F	toss the rockcress	*Boechera brachycarpa*	(T. & G.) Dorn
BOECH[a]	F	American rockcress	*Boechera*	Löve & Löve
BOEX2	F	second rockcress	*Boechera exilis*	(A. Nels.) Dorn
BOEHOL[a]	F	Holboell's rockcress	*Boechera holboellii*	(Hornem.) Löve & Löve
BOFES	F	spoonleaf rockcress	*Boechera fendleri* var. *spatifolia*	(S. Wats.) Greene; (Rydb.) Rollins
BOLE5	F	Lemmon's rockcress	*Boechera lemmonii*	(Wats.) Weber
BOLY	F	Lyall's rockcress	*Boechera lyallii*	(Wats.) Dorn
BOMI3	F	littleleaf rockcress	*Boechera microphylla*	(Nutt.) Dorn
BONU	F	Nuttall's rockcress	*Boechera nutallii*	(Robins.) Dorn
BOPU5	F	Fremont County rockcress	*Boechera pusilla*	(Rollins) Dorn
BOWI	F	Wind River rockcress	*Boechera williamsii*	(Rollins) Dorn
BUAM2	F	american thorough-wax	*Bupleurum americanum*	Coult. & Rose
CAAN7	F	northwestern Indian paintbrush	*Castilleja angustifolia*	(Nutt.) G. Don
CACU7	F	Cusick's paintbrush	*Castilleja cusickii*	Greenm.
CAEU	F	white mariposa lily	*Calochortus eurycarpus*	Wats.
CAFL7	F	yellow paintbrush	*Castilleja flava*	S. Wats.
CALE4	F	white marsh marigold	*Caltha leptosepala*	DC.
CALI4	F	narrow-leaved paintbrush	*Castilleja linariifolia*	Benth.

[a] Denotes species that did not have an USDA Plants Code as of April 2008. Local, six-letter plant codes were created for these species.

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CAMI12	F	scarlet paintbrush	*Castilleja miniata*	Dougl.
CAMI2	F	littlepod falseflax	*Camelina microcarpa*	Andrz.
CANU3	F	sego-lilly	*Calochortus nuttallii*	T. & G.
CANU4	F	musk thistle	*Carduus nutans*	L.
CAPA25	F	palish Indian-paintbrush	*Castilleja pallescens*	(Gray) Greenm.
CAPIL	F	longspike Indian paintbrush	*Castilleja pilosa* var. *longispica*	(S. Wats.) Rydb.; (A. Nels.) N. Holmgren
CAPU10	F	showy Indian-paintbrush	*Castilleja pulchella*	Rydb.
CARH4	F	alpine paintbrush	*Castilleja rhexifolia*	Rydb.
CARO2	F	harebell	*Campanula rotundifolia*	L.
CASTI2	F	Indian-paintbrush; paintbrush	*Castilleja*	Mutis ex L. f.
CEAR4	F	field chickweed	*Cerastium arvense*	L.
CHAN9	F	fireweed	*Chamerion angustifolium*	(L.) Holub
CHDOM	F	Douglas' dustymaiden	*Chaenactis douglasii* var. *montana*	(Hook.) Hook. & Arn.; M.E. Jones
CIRSI	F	thistle	*Cirsium*	P. Mill.
CISU	F	western thistle	*Cirsium subniveum*	Rydb.
CLMU5	F	lanceleaf springbeauty	*Claytonia multiscapa*	Rydb.
COLI2	F	narrow-leaf collomia	*Collomia linearis*	Nutt.
COPA3	F	small-flowered blue-eyed mary	*Collinsia parviflora*	Lindl.
COTE	F	diffuse collomia	*Collomia tenella*	Gray
COTR3	F	yellow coralroot	*Corallorrhiza trifida*	Chatelain
COWI2	F	spring coralroot	*Corallorrhiza wisteriana*	Conrad
CRAC2	F	tapertip hawksbeard	*Crepis acuminata*	Nutt.
CREPI	F	hawksbeard	*Crepis*	L.
CRIN4	F	gray hawksbeard	*Crepis intermedia*	Gray
CRMO4	F	low hawksbeard	*Crepis modocensis*	Greene
CRRU3	F	fiddleleaf hawksbeard	*Crepis runcinata*	(James) Torr. & Gray
CYEV	F	Evert's springparsley	*Cymopterus evertii*	R.L. Hartman & Kirkpatrick
CYLO10	F	Henderson's wavewing	*Cymopterus longilobus*	(Rydb.) W.A. Weber
CYMOP2	F	springparsley	*Cymopterus*	Raf.
CYNI3	F	snowline springparsley	*Cymopterus nivalis*	S. Wats.
CYTEA	F	turpentine wavewing	*Cymopterus terebinthinus* var. *albiflorus*	(Hook.) Torr. & Gray; (Torr. & Gray) M.E. Jones
DEIN5	F	mountain tansymustard	*Descurainia incana*	(Bernh. ex Fisch. & C.A. Mey.) Dorn
DEOC	F	duncecap larkspur	*Delphinium occidentale*	(Wats.) Wats.
DELPH	F	larkspur	*Delphinium*	L.
DENU2	F	upland larkspur	*Delphinium nuttallianum*	Pritz. ex Walp.
DIUN	F	longhorn steer's-head	*Dicentra uniflora*	Kellogg
DOCO	F	slimpod shooting star	*Dodecatheon conjugens*	Greene
DODEC	F	shooting star	*Dodecatheon*	L.

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DOPU	F	few-flowered shooting star	*Dodecatheon pulchellum*	(Raf.) Merrill
DRABA	F	draba	*Draba*	L.
DRAL4	F	slender whitlow-grass	*Draba albertina*	Greene
DRAU	F	golden draba	*Draba aurea*	Vahl ex Hornem.
DRCA4	F	cushion draba	*Draba cana*	Rydb.
DRCR2	F	thickleaved draba	*Draba crassifolia*	R. Grah.
DRDE	F	denseleaf draba	*Draba densifolia*	Nutt.
DRIN2	F	yellowstone whitlow-grass	*Draba incerta*	Payson
DRLO	F	lance-pod whitlow-grass	*Draba lonchocarpa*	Rydb.
DROL	F	few-seeded draba	*Draba oligosperma*	Hook.
DRPA	F	Payson's draba	*Draba paysonii*	J.F. Macbr.
ELRU	F	southwestern waterwort	*Elatine rubella*	Rydb.
EPCI	F	fringed willowherb	*Epilobium ciliatum*	Raf.
EPGLF2	F	glaucus willowherb	*Epilobium glaberrimum* var. *fastigiatum*	Barbey; (Nutt.) Trel. ex Jepson
EPHA	F	glandular willow-herb	*Epilobium halleanum*	Hausskn.
EPILO	F	willow-herb	*Epilobium*	L.
EPPA	F	marsh willowherb	*Epilobium palustre*	L.
EPPY4	F	smooth spike-primrose	*Epilobium pygmaeum*	(Speg.) Hoch & Raven
ERAS2	F	sanddune wallflower	*Erysimum asperum*	(Nutt.) DC.
ERCA2	F	tufted fleabane	*Erigeron caespitosus*	Nutt.
ERCO24	F	ballhead sandwort	*Eremogone congesta*	(Nutt.) S. Ikonnikov
ERCO5	F	long-leaved fleabane	*Erigeron corymbosus*	Nutt.
ERCOD	F	cutleaf daisy	*Erigeron compositus* var. *discoideus*	(Engelm.) A.A. Eat.; Gray
EREA	F	Eaton's fleabane	*Erigeron eatonii*	Gray
ERFL4	F	alpine golden buckwheat	*Eriogonum flavum*	Nutt.
ERFO3	F	beautiful fleabane	*Erigeron formosissimus*	Greene
ERGR2	F	slender fleabane	*Erigeron gracilis*	Rydb.
ERHOH2	F	Hooker's sandwort	*Eremogone hookeri* var. *hookeri*	(Nutt.) W.A. Weber
ERIGE2	F	daisy; fleabane	*Erigeron*	L.
ERLA	F	woolly fleabane	*Erigeron lanatus*	Hook.
ERLE6	F	rockslide yellow fleabane	*Erigeron leiomerus*	Gray
ERLI	F	desert yellow fleabane	*Erigeron linearis*	(Hook.) Piper
ERLO	F	shortray fleabane	*Erigeron lonchophyllus*	Hook.
ERNA5	F	dwarf fleabane	*Erigeron nanus*	Nutt.
EROC	F	buff fleabane	*Erigeron ochroleucus*	Nutt.
EROV	F	cushion buckwheat	*Eriogonum ovalifolium*	Nutt.
ERPES3	F	subalpine fleabane	*Erigeron peregrinus* var. *scaposus*	(Banks ex Pursh) Greene; (Torr. & Gray) Cronq.
ERPU2	F	shaggy fleabane	*Erigeron pumilus*	Nutt.

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ERPU9	F	basin fleabane	*Erigeron pulcherrimus*	Heller
ERRA2	F	taproot fleabane	*Erigeron radicatus*	Hook.
ERRY	F	northwestern fleabane	*Erigeron rydbergii*	Cronq.
ERSI3	F	alpine daisy	*Erigeron simplex*	Greene
ERSP4	F	showy fleabane	*Erigeron speciosus*	(Lindl.) DC.
ERTW	F	Tweedy's daisy	*Erigeron tweedyi*	Canby
ERUM	F	sulphur-flower buckwheat	*Eriogonum umbellatum*	Torr.
ERUR2	F	bear river fleabane	*Erigeron ursinus*	D.C. Eat.
ERYSI	F	wallflower	*Erysimum*	L.
EUCO36	F	eastern showy aster	*Eurybia conspicua*	(Lindl.) Nesom
EUEL2	F	elegant aster	*Eucephalus elegans*	Nutt.
EUGL13	F	gray aster	*Eucephalus glaucus*	Nutt.
EUIN9	F	thickstem aster	*Eurybia integrifolia*	(Nutt.) Nesom
FRAT	F	spotted fritillary	*Fritillaria atropurpurea*	Nutt.
FRSP	F	elkweed	*Frasera speciosa*	Dougl.
FRVE	F	woods strawberry	*Fragaria vesca*	L.
FRVI	F	Virginia strawberry	*Fragaria virginiana*	Duchesne
GAAR	F	blanket-flower	*Gaillardia aristata*	Pursh
GABI	F	thinleaf bedstraw	*Galium bifolium*	Wats.
GABO2	F	northern bedstraw	*Galium boreale*	L.
GARA2	F	pinyon groundsmoke	*Gayophytum ramosissimum*	T.& G.
GATR2	F	threepetal bedstraw	*Galium trifidum*	L.
GATR3	F	sweetscented bedstraw	*Galium triflorum*	Michx.
GEAL2	F	whitish gentian	*Gentiana algida*	Pallas
GEAM3	F	northern gentian	*Gentianella amarella*	(L.) Borner
GEMA4	F	largeleaf avens	*Geum macrophyllum*	Willd.
GERAN	F	geranium	*Geranium*	L.
GERI	F	white geranium	*Geranium richardsonii*	Fisch. & Trautv.
GEROT	F	Ross' avens	*Geum rossii* var. *turbinatum*	(R. Br.) Ser.; (Rydb.) C.L. Hitchc.
GETR	F	red avens	*Geum triflorum*	Pursh
GEUM	F	avens	*Geum*	L.
GEVI2	F	sticky purple geranium	*Geranium viscosissimum*	F. & M.
GYPA2	F	smallflower gymnosteris	*Gymnosteris parvula*	Heller
HAPLO11	F	goldenweed	*Haplopappus*	Cass.
HEALA	F	alpine sweetvetch	*Hedysarum alpinum* var. *americanum*	L.; Michx.
HEPA11	F	small-leaved alumroot	*Heuchera parvifolia*	Nutt.
HEQU2	F	nodding helianthella	*Helianthella quinquenervis*	(Hook.) Gray
HESPL	F	common cowparsnip	*Heracleum sphondylium* var. *lanatum*	L.; (Michx.) Dorn

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HEUN	F	one-flowered helianthella	*Helianthella uniflora*	(Nutt.) T. & G.
HIAL2	F	white-flowered hawkweed	*Hieracium albiflorum*	Hook.
HIERA	F	hawkweed	*Hieracium*	L.
HITRG2	F	slender hawkweed	*Hieracium triste* var. *gracile*	Willd. ex Spreng.; (Hook.) Gray
HYGR5	F	graylocks four-nerve daisy	*Hymenoxys grandiflora*	(T. & G.) Parker
IPAG	F	scarlet gilia	*Ipomopsis aggregata*	(Pursh) V. Grant
IPSP	F	spiked ipomopsis	*Ipomopsis spicata*	(Nutt.) V. Grant
IVGO	F	Gordon's ivesia	*Ivesia gordonii*	(Hook.) Torr. & Gray
LEFR4	F	Fremont's bladderpod	*Lesquerella fremontii*	Rollins & Shaw
LEPY2	F	alpine bitteroot	*Lewisia pygmaea*	(Gray) B.L. Robins.
LERE7	F	bitterroot	*Lewisia rediviva*	Pursh
LESQU	F	bladderpod	*Lesquerella*	S. Wats.
LIGLR	F	bulbous woodland-star	*Lithophragma glabrum* var. *ramulosum*	Nutt.; (Suksdorf) Boivin
LILE3	F	prairie flax	*Linum lewisii*	Pursh
LINUM	F	flax	*Linum*	L.
LIRU4	F	western gromwell	*Lithospermum ruderale*	Dougl.
LOAT	F	tapertip desertparsley	*Lomatium attenuatum*	Evert
LOCO4	F	cous biscuit-root	*Lomatium cous*	(Wats.) Coult. & Rose
LODIM	F	carrotleaf biscuitroot	*Lomatium dissectum* var. *multifidum*	(Nutt.) Mathias & Constance
LOMAT	F	biscuit-root; desert-parsley	*Lomatium*	Raf.
LOOR	F	Northern Idaho biscuitroot	*Lomatium orientale*	Coult. & Rose
LOTR2	F	nineleaf biscuitroot	*Lomatium triternatum*	(Pursh) Coult. & Rose
LUAR3	F	silvery lupine	*Lupinus argenteus*	Pursh
LULEU2	F	Utah lupine	*Lupinus lepidus* var. *utahensis*	Dougl. ex Lindl.; (S. Wats.) C.L. Hitchc.
LUPIN	F	lupine	*Lupinus*	L.
LUPO2	F	bigleaf lupine	*Lupinus polyphyllus*	Lindl.
LUSE4	F	silky lupine	*Lupinus sericeus*	Pursh
MACA2	F	hoary tansyaster	*Machaeranthera canescens*	(Pursh) Gray
MAST4	F	starry false lily of the valley	*Maianthemum stellatum*	(L.) Link
MEAL7	F	alpine bluebells	*Mertensia alpina*	(Torr.) G. Don
MECI3	F	tall fringed bluebells	*Mertensia ciliata*	(Torr.) G. Don
MERTE	F	bluebells	*Mertensia*	Roth
MEVI4	F	oblongleaf bluebells	*Mertensia viridis*	(A. Nels.) A. Nels.
MIAU3	F	Columbian stitchwort	*Minuartia austromontana*	S.J. Wolf & Packer
MIGLJ	F	James' monkeyflower	*Mimulus glabratus* var. *jamesii*	Kunth; (Torr. & Gray ex Benth.) Gray
MIMA3	F	House's stitchwort	*Minuartia macrantha*	(Rydb.) House
MINU4	F	Nuttall's sandwort	*Minuartia nuttallii*	(Pax) Briq.
MIOB2	F	twinflower sandwort	*Minuartia obtusiloba*	(Rydb.) House

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MONU	F	poverty weed	*Monolepis nuttalliana*	(Schultes) Greene
MOUN2	F	single delight	*Moneses uniflora*	(L.) Gray
MUMO	F	mountain muhly	*Muhlenbergia montana*	(Nutt.) A.S. Hitchc.
NONI	F	meadow prairie-dandelion	*Nothocalais nigrescens*	(Henderson) Heller
ORAL4	F	tundra aster	*Oreostemma alpigenum*	(Torr. & Gray) Greene
ORFA	F	clustered broomrape	*Orobanche fasciculata*	Nutt.
ORLU2	F	yellow owl-clover	*Orthocarpus luteus*	Nutt.
ORSE	F	sidebells wintergreen	*Orthilia secunda*	(L.) House
ORTO	F	Tolmie's owl's-clover	*Orthocarpus tolmiei*	Hook. & Arn.
ORUNO2	F	oneflowered broomrape	*Orobanche uniflora* var. *occidentalis*	L.; (Greene) Taylor & MacBryde
OSBE	F	sweetcicely	*Osmorhiza berteroi*	Hook. & Arn.
OSDE	F	bluntseed sweetroot	*Osmorhiza depauperata*	Phil.
OSMOR	F	sweetroot	*Osmorhiza*	Raf.
OSOC	F	western sweet-cicely	*Osmorhiza occidentalis*	(Nutt.) Torr.
OSPU	F	purple sweetroot	*Osmorhiza purpurea*	(Coult. & Rose) Suksdorf
OXCA4	F	slender crazyweed	*Oxytropis campestris*	(L.) DC.
OXDE2	F	pendent-pod crazyweed	*Oxytropis deflexa*	(Pall.) DC.
OXLA2	F	haresfoot locoweed	*Oxytropis lagopus*	Nutt.
OXPO	F	stalkpod locoweed	*Oxytropis podocarpa*	Gray
OXSE	F	white locoweed	*Oxytropis sericea*	Nutt.
PACA15	F	woolly groundsel	*Packera cana*	(Hook.) W.A. Weber & A. Löve
PADI11	F	splitleaf groundsel	*Packera dimorphophylla*	(Greene) W.A. Weber & A. Löve
PAFI3	F	fringed grass-of-parnassus	*Parnassia fimbriata*	Koenig
PAST10	F	Rocky Mountain groundsel	*Packera streptanthifolia*	(Greene) W.A. Weber & A. Löve
PASU40	F	cleftleaf groundsel	*Packera subnuda*	(DC.) D.K. Trock & T.M. Barkl.
PEBRP2	F	Payson's lousewort	*Pedicularis bracteosa* var. *paysoniana*	Benth.; (Pennell) Cronq.
PECO	F	coiled lousewort	*Pedicularis contorta*	Benth.
PEDE4	F	hotrock penstemon	*Penstemon deustus*	Dougl. ex Lindl.
PEDIC	F	lousewort	*Pedicularis*	L.
PEGR2	F	elephant's head	*Pedicularis groenlandica*	Retz.
PEHU	F	low beardtongue	*Penstemon humilis*	Nutt. ex Gray
PENST	F	penstemon	*Penstemon*	Schmidel
PEPA3	F	Parry's lousewort	*Pedicularis parryi*	Gray
PEPR2	F	small-flowered penstemon	*Penstemon procerus*	Dougl.
PERA2	F	mat-root penstemon	*Penstemon radicosus*	A. Nels.
PERAA2	F	sickletop lousewort	*Pedicularis racemosa* var. *alba*	Dougl. ex Benth.; Pennell
PERY	F	Rydberg's penstemon	*Penstemon rydbergii*	A. Nels.
PEST2	F	Rocky Mountain penstemon	*Penstemon strictus*	Benth.

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PHHA	F	silverleaf phacelia	*Phacelia hastata*	Dougl.
PHHO	F	Hood's phlox	*Phlox hoodii*	Rich.
PHLO2	F	long-leaf phlox	*Phlox longifolia*	Nutt.
PHLOX	F	phlox	*Phlox*	L.
PHMU3	F	many-flowered phlox	*Phlox multiflora*	A. Nels.
PHMU4	F	musk phlox	*Phlox muscoides*	Nutt.
PHPU12	F	prickly phlox	*Phlox pungens*	Dorn
PHPU5	F	cushion phlox	*Phlox pulvinata*	(Wherry) Cronq.
PHSE	F	silky phacelia	*Phacelia sericea*	(Graham) Gray
PLDI3	F	scentbottle	*Platanthera dilatata*	(Pursh) Lindl. ex Beck
PLSCH	F	sleeping popcornflower	*Plagiobothrys scouleri* var. *hispidulus*	(Greene) Dorn
POAR7	F	tall cinquefoil	*Potentilla arguta*	Pursh
POBI10	F	tansy cinquefoil	*Potentilla bipinnatifida*	Dougl. ex Hook.
POBI6	F	american bistort	*Polygonum bistortoides*	Pursh
POBR5	F	sparseleaf cinquefoil	*Potentilla brevifolia*	Nutt. ex Torr. & Gray
POCO13	F	elegant cinquefoil	*Potentilla concinna*	Richards.
PODI2	F	varileaf cinquefoil	*Potentilla diversifolia*	Lehm.
PODO4	F	Douglas' knotweed	*Polygonum douglasii*	Greene
POGL9	F	sticky cinquefoil	*Potentilla glandulosa*	Lindl.
POGR9	F	slender cinquefoil	*Potentilla gracilis*	Dougl.
POHI6	F	woolly cinquefoil	*Potentilla hippiana*	Lehm.
POHO2	F	Hooker cinquefoil	*Potentilla hookeriana*	Lehm.
POOV2	F	sheep cinquefoil	*Potentilla ovina*	Macoun
POPE8	F	prairie cinquefoil	*Potentilla pensylvanica*	L.
POTEN	F	cinquefoil	*Potentilla*	L.
POUN2	F	oneflower cinquefoil	*Potentilla uniflora*	Ledeb.
POVI	F	sticky polemonium	*Polemonium viscosum*	Nutt.
POVI3	F	viviparous knotweed	*Polygonum viviparum*	L.
PRTR4	F	roughfruit fairybells	*Prosartes trachycarpa*	S. Wats.
PTAN2	F	woodland pinedrops	*Pterospora andromedea*	Nutt.
PYAS	F	pink wintergreen	*Pyrola asarifolia*	Michx.
PYCH	F	greenflowered wintergreen	*Pyrola chlorantha*	Sw.
PYIN3	F	many-stemmed goldenweed	*Pyrrocoma integrifolia*	(Porter ex Gray) Greene
PYMI	F	lesser wintergreen	*Pyrola minor*	L.
PYPI2	F	white vein pyrola	*Pyrola picta*	Sm.
PYROL	F	wintergreen	*Pyrola*	L.
PYUN2	F	plantain goldenweed	*Pyrrocoma uniflora*	(Hook.) Greene
RAGLE	F	elliptical buttercup	*Ranunculus glaberrimus* var. *ellipticus*	Hook.; (Greene) Greene

USDA code	LF	Common name	Scientific name	Author
RAUN	F	little buttercup	*Ranunculus uncinatus*	D. Don ex G. Don
RUAQF	F	western dock	*Rumex aquaticus* var. *fenestratus*	L.; (Greene) Dorn
SAOD2	F	brook saxifrage	*Saxifraga odontoloma*	Piper
SARH2	F	diamondleaf saxifrage	*Saxifraga rhomboidea*	Greene
SECR	F	thickleaf ragwort	*Senecio crassulus*	Gray
SEFR3	F	dwarf mountain ragwort	*Senecio fremontii*	T. & G.
SEHY	F	tall groundsel	*Senecio hydrophiloides*	Rydb.
SEHY2	F	water ragwort	*Senecio hydrophilus*	Nutt.
SEIN2	F	lambstongue ragwort	*Senecio integerrimus*	Nutt.
SEIN4	F	ledge stonecrop	*Sedum integrifolium*	(Raf.) A. Nels.
SELA	F	lance-leaved stonecrop	*Sedum lanceolatum*	Torr.
SELU	F	black-tipped butterweed	*Senecio lugens*	Rich.
SENEC	F	groundsel; ragwort; butterweed	*Senecio*	L.
SERA	F	openwoods ragwort	*Senecio rapifolius*	Nutt.
SERH	F	red-pod stonecrop	*Sedum rhodanthum*	Gray
SERO2	F	roseroot stonecrop	*Sedum rosea*	(L.) Scop.
SESE2	F	tall ragwort	*Senecio serra*	Hook.
SEST2	F	wormleaf stonecrop	*Sedum stenopetalum*	Pursh
SETR	F	arrowleaf groundsel	*Senecio triangularis*	Hook.
SIACS2	F	moss campion	*Silene acaulis* var. *subacaulescens*	(L.) Jacq.; (F.N. Williams) Fern. & St. John
SIAN2	F	sleepy catchfly	*Silene antirrhina*	L.
SIDR	F	Drummond campion	*Silene drummondii*	Hook.
SIKI	F	King's campion	*Silene kingii*	(S. Wats.) Bocquet
SIPA4	F	Parry's silene	*Silene parryi*	(Wats.) Hitchc. & Mag.
SIPR	F	creeping sibbaldia	*Sibbaldia procumbens*	L.
SOCA6	F	Canada goldenrod	*Solidago canadensis*	L.
SOLID	F	goldenrod	*Solidago*	L.
SOMO	F	velvety goldenrod	*Solidago mollis*	Bartl.
SOMUS	F	manyray goldenrod	*Solidago multiradiata* var. *scopulorum*	Ait.; Gray
SOVE6	F	threenerve goldenrod	*Solidago velutina*	DC.
SPRU	F	red sandspurry	*Spergularia rubra*	(L.) J.& K. Presl
STAC	F	stemless mock goldenweed	*Stenotus acaulis*	(Nutt.) Nutt.
STAM2	F	clasping-leaved twisted-stalk	*Streptopus amplexifolius*	(L.) DC.
STCA	F	northern starwort	*Stellaria calycantha*	(Ledeb.) Bong.
STELL	F	starwort; chickweed	*Stellaria*	L.
STENO7	F	mock goldenweed	*Stenotus*	Nutt.
STLO2	F	longstalk starwort	*Stellaria longipes*	Goldie
STMO2	F	longstalk starwort	*Stellaria monantha*	Hultén

USDA code	LF	Common name	Scientific name	Author
STST5	F	narrowleaf mock goldenweed	*Stenotus stenophyllus*	(Gray) Greene
SWPE	F	felwort	*Swertia perennis*	L.
SYBO2	F	northern bog aster	*Symphyotrichum boreale*	(Torr. & Gray) A.& D. Löve
SYFO2	F	alpine leafybract aster	*Symphyotrichum foliaceum*	(Lindl. ex DC.) Nesom
SYSP	F	western mountain aster	*Symphyotrichum spathulatum*	(Lindl.) Nesom
TACE	F	horned dandelion	*Taraxacum ceratophorum*	(Ledeb.) DC.
TAER2	F	wool-bearing dandelion	*Taraxacum eriophorum*	Rydb.
TAOF	F	common dandelion	*Taraxacum officinale*	Weber
TARAX	F	dandelion	*Taraxacum*	G.H. Weber ex Wiggers
TEACA2	F	stemless four-nerve daisy	*Tetraneuris acaulis* var. *acaulis*	(Pursh) Greene
THALI2	F	meadowrue	*Thalictrum*	L.
THFE	F	Fendler's meadowrue	*Thalictrum fendleri*	Engelm.
THOC	F	western meadowrue	*Thalictrum occidentale*	Gray
THSPS	F	fewflower meadow-rue	*Thalictrum sparsiflorum* var. *saximontanum*	Turcz. ex Fisch. & C.A. Mey.; Boivin
THVE	F	veiny meadowrue	*Thalictrum venulosum*	Trel.
TOLY	F	Lyall's goldenweed	*Tonestus lyallii*	(Gray) A. Nels.
TOSP	F	sword Townsend daisy	*Townsendia spathulata*	Nutt.
TRAGO	F	goatsbeard	*Tragopogon*	L.
TRAL8	F	American globeflower	*Trollius albiflorus*	(Gray) Rydb.
TRDA2	F	alpine clover	*Trifolium dasyphyllum*	T. & G.
TRDU	F	goat's beard	*Tragopogon dubius*	Scop.
TRLA30	F	Jack-go-to-bed-at-noon	*Tragopogon lamottei*	Rouy
TRNA2	F	dwarf clover	*Trifolium nanum*	Torr.
TRPA6	F	marsh arrowgrass	*Triglochin palustris*	L.
VEAN2	F	water speedwell	*Veronica anagallis-aquatica*	L.
VERON	F	speedwell	*Veronica*	L.
VEWO2	F	American alpine speedwell	*Veronica wormskjoldii*	Roem. & Schult.
VIOLA	F	violet	*Viola*	L.
VIPUV	F	goosefoot violet	*Viola purpurea* var. *venosa*	Kellogg; (S. Watson) Brainerd
ZIEL2	F	glaucous deathcamas	*Zigadenus elegans*	Pursh
ZIPA2	F	foothill deathcamas	*Zigadenus paniculatus*	(Nutt.) S. Wats.
ZIVEG	F	grassy deathcamas	*Zigadenus venenosus* var. *gramineus*	S. Wats.; (Rydb.) Walsh ex M.E. Peck
Grasses				
ACLE9	G	Letterman's needlegrass	*Achnatherum lettermanii*	(Vasey) Barkworth
ACNE9	G	Columbia needlegrass	*Achnatherum nelsonii*	(Scribn.) Barkworth
ACOC3	G	western needlegrass	*Achnatherum occidentale*	(Thurb.) Barkworth

USDA code	LF	Common name	Scientific name	Author
AGHU	G	alpine bentgrass	*Agrostis humilis*	Vasey
AGID	G	Idaho bentgrass	*Agrostis idahoensis*	Nash
AGSC5	G	tickle-grass	*Agrostis scabra*	Willd.
AGVA	G	variable bentgrass	*Agrostis variabilis*	Rydb.
BRCA5	G	mountain brome	*Bromus carinatus*	H. & A.
BRCI2	G	fringed brome	*Bromus ciliatus*	L.
BRIN2	G	smooth brome	*Bromus inermis*	Leys.
BROMU	G	brome	*Bromus*	L.
BRPU6	G	hairy woodland brome	*Bromus pubescens*	Muhl. ex Willd.
BRTE	G	cheatgrass	*Bromus tectorum*	L.
BRVU	G	Columbia brome	*Bromus vulgaris*	(Hook.) Shear
CACA4	G	bluejoint reedgrass	*Calamagrostis canadensis*	(Michx.) Beauv.
CAIN	G	northern reedgrass	*Calamagrostis inexpansa*	Gray
CAPU	G	purple reedgrass	*Calamagrostis purpurascens*	R. Br.
CASC	G	ditch reed-grass	*Calamagrostis scopulorum*	M.E. Jones
CAST36	G	narrow-spiked reedgrass	*Calamagrostis stricta*	(Brid.) Kindb.
DAIN	G	timber oatgrass	*Danthonia intermedia*	Vasey
DAPA2	G	Parry's oatgrass	*Danthonia parryi*	Scribn.
DASP2	G	poverty oatgrass	*Danthonia spicata*	(L.) Beauv.
DEAT2	G	Mountain Hairgrass	*Deschampsia atropurpurea*	(Wahl.) Scheele
DECE	G	tufted hairgrass	*Deschampsia cespitosa*	(L.) Beauv.
DEEL	G	slender hairgrass	*Deschampsia elongata*	(Hook.) Munro
ELCI2[b]	G	Great Basin wildrye	*Elymus cinereus*	Scribn. & Merr.
ELEL5	G	squirreltail	*Elymus elymoides*	(Raf.) Swezey
ELGL	G	blue wildrye	*Elymus glaucus*	Buckl.
ELLA3	G	streambank wheatgrass	*Elymus lanceolatus*	(Scribn. & Sm.) Gould
ELRE4	G	quackgrass	*Elymus repens*	(L.) Gould
ELSM3	G	western wheatgrass	*Elymus smithii*	(Rydb.) Gould
ELSP3	G	bluebunch wheatgrass	*Elymus spicatus*	(Pursh) Gould
ELTR3	G	beardless wildrye	*Elymus triticoides*	Buckl.
ELTR7	G	slender wheatgrass	*Elymus trachycaulus*	(Link) Gould ex Shinners
FEAR3	G	tall fescue	*Festuca arundinacea*	Schreb.
FEBR	G	alpine fescue	*Festuca brachyphylla*	J.A. Schultes ex J.A. & J.H. Schultes
FEID	G	Idaho fescue	*Festuca idahoensis*	Elmer
FERU2	G	red fescue	*Festuca rubra*	L.
FESA	G	Rocky Mountain fescue	*Festuca saximontana*	Rydb.

[b] Species not encountered in field but mentioned in report.

USDA code	LF	Common name	Scientific name	Author
FEVIK2	G	northern fescue	*Festuca viviparoidea ssp. krajinae*	Krajina ex Pavlick; Frederiksen
GLGR	G	american mannagrass	*Glyceria grandis*	Wats
GLST	G	fowl mannagrass	*Glyceria striata*	(Lam.) A. S. Hitchc.
HECO26	G	needle and thread	*Hesperostipa comata*	(Trin. & Rupr.) Barkworth
HECOC9	G	needle and thread	*Hesperostipa comata* var. *comata*	J.A. Schultes ex J.A. & J.H. Schultes
KOMA	G	prairie junegrass	*Koeleria macrantha*	(Ledeb.) Schultes
LEKI2	G	spike fescue	*Leucopoa kingii*	(Wats.) Weber
MEBU	G	oniongrass	*Melica bulbosa*	Geyer
PHAL2	G	alpine timothy	*Phleum alpinum*	L.
PIEX3	G	little ricegrass	*Piptatherum exiguum*	(Thurb.) Barkworth, comb. nov. ined.
PIMI7	G	littleseed ricegrass	*Piptatherum micranthum*	(Trin. & Rupr.) Barkworth
POA	G	bluegrass	*Poa*	L.
POAL2	G	alpine bluegrass	*Poa alpina*	L.
POAR2	G	arctic bluegrass	*Poa arctica*	R. Br.
POAR21	G	Wasatch bluegrass	*Poa arnowiae*	Soreng
POAR3	G	plains bluegrass	*Poa arida*	Vasey
POCU2	G	little mountain bluegrass	*Poa curtifolia*	Scribn.
POCU3	G	Cusick's bluegrass	*Poa cusickii*	Vasey
POFE	G	muttongrass	*Poa fendleriana*	(Steud.) Vasey
POGLR	G	timberline bluegrass	*Poa glauca* var. *rupicola*	Vahl; (Nash ex Rydb.) Boivin
POGR	G	slender bluegrass	*Poa gracillima*	Vasey
POJU	G	alkali bluegrass	*Poa juncifolia*	Scribn.
POLE3	G	Letterman's bluegrass	*Poa lettermanii*	Vasey
POPA3	G	patterson bluegrass	*Poa pattersonii*	(Vasey) A. & D. Love & Kapoor
POPR	G	Kentucky bluegrass	*Poa pratensis*	L.
PORE	G	nodding bluegrass	*Poa reflexa*	Vasey & Scribn. ex Vasey
POSE	G	Sandberg bluegrass	*Poa secunda*	Presl
POTR2	G	rough bluegrass	*Poa trivialis*	L.
POWH2	G	Wheeler's bluegrass	*Poa wheeleri*	Vasey
PUCU	G	Nuttall's alkaligrass	*Puccinellia nuttalliana*	Weath.
STIPA	G	needlegrass	*Stipa*	L.
TRSP2	G	spike trisetum	*Trisetum spicatum*	(L.) Richter
Grasslikes				
CAAL6	GL	black-and-white-scaled sedge	*Carex albonigra*	Mack.
CAAQ	GL	aquatic sedge	*Carex aquatilis*	Wahl.
CAAT13	GL	different nerve sedge	*Carex atrata*	auct. p.p. non L.

USDA code	LF	Common name	Scientific name	Author
CAAU3	GL	golden sedge	*Carex aurea*	Nutt.
CABI10	GL	arctic hare's-foot sedge	*Carex bipartita*	All.
CABRP3	GL	Engelmann's sedge	*Carex breweri* var. *paddoensis*	Boott; (Suksdorf) Cronq.
CACA11	GL	silvery sedge	*Carex canescens*	L.
CACA13	GL	capitate sedge	*Carex capitata*	L.
CADI6	GL	two-seeded sedge	*Carex disperma*	Dewey
CAEL3	GL	blackroot sedge	*Carex elynoides*	Holm
CAFOV	GL	native sedge	*Carex foetida* var. *vernacula*	All.; (Bailey) Kükenth.
CAGE2	GL	elk sedge	*Carex geyeri*	Boott
CAHA6	GL	Hayden's sedge	*Carex haydeniana*	Olney
CAHO5	GL	Hood's sedge	*Carex hoodii*	Boott
CALE9	GL	Sierra hare sedge	*Carex leporinella*	Mack.
CALEP4	GL	lakeshore sedge	*Carex lenticularis* var. *pallida*	Michx.; (W. Boott) Dorn
CALI7	GL	mud sedge	*Carex limosa*	L.
CAMA9	GL	falkland island sedge	*Carex macloviana*	d'Urv.
CAMI10	GL	shortleaved sedge	*Carex misandra*	R. Br.
CAMI7	GL	small-winged sedge	*Carex microptera*	Mack.
CANA2	GL	spike sedge	*Carex nardina*	Fries
CANE3	GL	Nelson's sedge	*Carex nelsonii*	Mackenzie
CANI2	GL	black alpine sedge	*Carex nigricans*	C.A. Mey.
CANOS2	GL	Steven's sedge	*Carex norvegica* var. *stevenii*	Retz.; (Holm) Dorn
CAOB4	GL	obtuse sedge	*Carex obtusata*	Lilj.
CAOR	GL	grassyslope sedge	*Carex oreocharis*	Holm
CAPA31	GL	payson sedge	*Carex paysonis*	Clokey
CAPE42	GL	wooly sedge	*Carex pellita*	Muhl ex Willd.
CAPH2	GL	dunhead sedge	*Carex phaeocephala*	Piper
CAPR7	GL	meadow sedge	*Carex praticola*	Rydb.
CAPY3	GL	pyrenean sedge	*Carex pyrenaica*	Wahlenb.
CARA6	GL	raynolds' sedge	*Carex raynoldsii*	Dewey
CAREX	GL	sedge	*Carex*	L.
CARO5	GL	Ross' sedge	*Carex rossii*	Boott
CARU3	GL	curly sedge	*Carex rupestris*	All.
CASA10	GL	rock sedge	*Carex saxatilis*	L.
CASC10	GL	northern singlespike sedge	*Carex scirpoidea*	Michx.
CASC12	GL	Holm's Rocky Mountain sedge	*Carex scopulorum*	Holm
CASCP2	GL	western singlespike sedge	*Carex scirpoidea* var. *pseudoscirpoidea*	Michx.; (Rydb.) Cronq.
CAST40	GL	needleleaf sedge	*Carex stenophylla*	Wahlenb.
CAUT	GL	beaked sedge	*Carex utriculata*	Boott

USDA code	LF	Common name	Scientific name	Author
CAVA3	GL	valley sedge	*Carex vallicola*	Dewey
CAVE6	GL	inflated sedge	*Carex vesicaria*	L.
CAVU2	GL	fox sedge	*Carex vulpinoidea*	Michx.
CAXE	GL	whitescale sedge	*Carex xerantica*	Bailey
ELQU2	GL	fewflower spikerush	*Eleocharis quinqueflora*	(F.X. Hartmann) Schwarz
ERAN6	GL	tall cottongrass	*Eriophorum angustifolium*	Honckeny
JUBA	GL	baltic rush	*Juncus balticus*	Willd.
JUCO2	GL	Colorado rush	*Juncus confusus*	Coville
JUDR	GL	Drummond's rush	*Juncus drummondii*	E. Meyer
JUEN	GL	swordleaf rush	*Juncus ensifolius*	Wikst.
JUHA	GL	Hall's rush	*Juncus hallii*	Engelm.
JUME3	GL	Mertens' rush	*Juncus mertensianus*	Bong.
JUPA	GL	Parry's rush	*Juncus parryi*	Engelm.
JUTR4	GL	three-hulled rush	*Juncus triglumis*	L.
KOMY	GL	Bellardi bog sedge	*Kobresia myosuroides*	(Vill.) Fiori
LUMU2	GL	common woodrush	*Luzula multiflora*	(Ehrh.) Lej.
LUPA4	GL	small-flowered woodrush	*Luzula parviflora*	(Ehrh.) Desv.
LUSP4	GL	spike woodrush	*Luzula spicata*	(L.) DC.
LUWA	GL	Wahlenberg's woodrush	*Luzula wahlenbergii*	Rupr.
Ferns and Horsetails				
CRAC3	FH	American rockbrake	*Cryptogramma acrostichoides*	R. Br.
CYFR2	FH	brittle bladder-fern	*Cystopteris fragilis*	(L.) Bernh.
EQAR	FH	field horsetail	*Equisetum arvense*	L.
EQHYA	FH	scouringrush horsetail	*Equisetum hyemale* var. *affine*	L.; (Engelm.) A.A. Eat.
EQVA	FH	variegated scouring rush	*Equisetum variegatum*	Schleich. ex F. Weber & D.M.H. Mohr

Appendix 3: Available Water Capacity of Mineral Soils by Texture

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Appendix 3. Available water capacity (AWC) of mineral soils as related to soil texture.

General term	Texture[a]	Probable range on basis of texture[b] (in/in)	Total permissible range[c] (in/in)
Fine	Clay	.12-.15	.12-.17
	Silty clay	.13-.16	.12-.17
	Sandy clay	.13-.16	.12-.17
Moderately fine	Silty clay loam	.18-.19	.17-.19
	Clay loam	.17-.18	.17-.19
	Sandy clay loam	.17-.18	.17-.19
Medium	Silt loam	.15-.17	.12-.17
	Loam	.14-.16	.12-.17
	Very fine sandy loam	.14-.16	.12-.17
Moderately coarse	Fine sandy loam	.10-.12	.08-.12
	Sandy loam	.09-.11	.08-.12
	Loamy very fine sand	.09-.11	.08-.12
	Loamy fine sand	.08-.10	.08-.12
Coarse	Loamy sand	.06-.08	.06-.08
	Very fine sand	.06-.08	.06-.08
	Fine sand	.06-.08	.06-.08
	Sand	.06-.08	.06-.08
Very coarse	Coarse sand and gravel	.03-.06	.03-.06

[a] Where gravel or other coarse fragments are present, values for textures shown above should be reduced by the percentage of coarse fragments in the soil mass.

[b] These figures represent the probable ranges for each textural class based only on texture. Soil structure, organic matter content, stratification, etc., may alter these figures but only within the total permissible range shown above.

[c] AWC values for each textural class should not span more than 0.03 in/in on SCS-SOILS-5 forms.

Appendix 4: Cross-reference Between Ecological Types and Soil Map Unit Components

Table 4-1 provides a cross-reference between the ecological types presented in this document and the soil map unit components from the eastern slope of the Wind River Range presented as part of the map unit descriptions of the Shoshone National Forest Soil Survey (USDA, NRCS 2008). The tables are organized by soil map unit and include the following:

- Component—the soil map unit component, may include soil series name, soil subgroup, or miscellaneous areas;
- Vegetation—the vegetation type (functional group, vegetation series, and habitat type);
- Ecological Type—the ecological type synonymous with the soil map unit component; and
- Percent—the areal extent of the ecological type in each map unit (may differ slightly from the soil map unit component percentages due to disparities mentioned below).

Objective two of this study was the simultaneous classification of the soil map unit components and ecological types of the eastern slope of the Wind River Range. Objective three was the publication of the ecological type classification such that is was compatible with the spatial and tabular data from the Wind River Range portion of the National Cooperative Soil Survey of the Shoshone National Forest. The last two objectives were completed successfully. However, a few minor disparaties exist between the ecological type classification and the soil map unit components related to differences between National Cooperative Soil Survey (NCSS) and Terrestrial Ecological Unit Inventory (TEUI) protocols. These disparities are explained in Table 4-2.

Table 4-1. Cross-reference among ecological types, soil map units, and soil map unit components, ecological type classification of the eastern slope of the Wind River Range, Shoshone National Forest, WY.

Map unit	Component	Vegetation	Ecological type	Percent of map unit
311	Rock Outcrop	NA	NA	60
	Enentah	NA	NA	20
	Dystrocryepts and similar soils	PIAL/VASC	PIAL/VASC, Jeru Family ET	10
		PIAL/VASC	PIAL/VASC, Sig Family ET	10
12L	Lolo	PIFL2/JUCOD	PIFL2/JUCOD, Lolo Family ET	40
	Rock Outcrop	NA	NA	15
	Shawmut	PSMEG/JUCOD	PSMEG/JUCOD, Shawmut Family ET	15
	Paunsaugunt	ELSP3-POSE-STENO7	ELSP3-POSE-STENO7, Paunsaugunt Family ET	10
	Tyzak	PIFL2/JUCOD	PIFL2/JUCOD, Tyzak Family ET	10
	Winspect	ARTRV2/ELSP3	ARTRV2/ELSP3, Winspect Family ET	10
15L	Winspect	ARTRV2/ELSP3	ARTRV2/ELSP3, Winspect Family ET	45
	Kiev	ARTRV2/FEID	ARTRV2/FEID, Kiev Family ET	20
	Bigsheep	ARTRR4/ELSP3	ARTRR4/ELSP3, Bigsheep Family ET	15
	Saddlehorse	PIFL2/LEKI2	PIFL2/LEKI2, Saddlehorse Family ET	10
	Bullflat	POTR5/GEVI2	POTR5/GEVI2, Bullflat Family ET	5
	Shawmut	ARTRV2/FEID	ARTRV2/FEID, Shawmut Family ET	5
43L	Cloud Peak	PSMEG/MARE11	PSMEG/MARE11, Cloud Peak Family ET	40
	Redfist	PSMEG/ACGL	PSMEG/ACGL, Redfist Family ET	30
	Frisco	ABLA/MARE11	ABLA/MARE11, Frisco Family ET	15
	Bullflat	POTR5/GEVI2	POTR5/GEVI2, Bullflat Family ET	5
	Hierro	ABLA/ARCO9 - CAD	ABLA/ARCO9 - CAD, Hierro Family ET	5
	NA	PSMEG/SYORU	PSMEG/SYORU, Typic Calciustepts ET	5
43LF	Como	PICOL/ARCO9	PICOL/ARCO9, Como Family ET	40
	Agneston	PICOL/MARE11	PICOL/MARE11, Agneston	25

Map unit	Component	Vegetation	Ecological type	Percent of map unit
			Family ET	
	Rock Outcrop	NA	NA	20
	Marosa	ABLA/VASC	ABLA/VASC, Marosa Family ET	5
	NA	PIAL Series	PIAL Series, Marosa Family ET	5
	Telcher	PICOL/VASC	PICOL/VASC, Telcher Family ET	5
44L	Bullflat	POTR5/GEVI2	POTR5/GEVI2, Bullflat Family ET	55
	Ledgefork	POTR5/SYORU - Boulder	POTR5/SYORU - Boulder, Ledgefork Family ET	40
	Caryville	POTR5/COSE16-ALVIS	POTR5/COSE16-ALVIS, Caryville Family ET	5
106D	NA	PICOL Series	PICOL Series, Corbly Family ET	95
	Rock Outcrop	NA	NA	5
166D	NA	ARTRV2/FEID	ARTRV2/FEID, Corbly Family ET 166D	40
	NA	ARTRV2/FEID	ARTRV2/FEID, Lithic Argiustolls ET	20
	Rock Outcrop	NA	NA	5
302/302L	Moose River	Salix/Carex	Salix/Carex, Moose River Family ET	80
	Elvick	Oxyaquic Soils	Oxyaquic Soils, Elvick Family ET	15
	Southpaw	NA	NA	NA
	Water	NA	NA	5
304L	Agneston	GEROT-CAEL3 Alpine Turf	GEROT-CAEL3 Alpine Turf, Agneston Family ET	30
	McCall	GEROT Alpine Fellfield	GEROT Alpine Fellfield, McCall Family ET	30
	Rubble-land	NA	NA	12
	Elting	ABLA/RIMO2	ABLA/RIMO2, Elting Family ET	5
	Hargran	Late snowbank vegetation	Late snowbank vegetation, Hargran Family ET	5
	Klootch	Krummholz	Krummholz, Klootch Family ET	5
	McCall	SAREN2/KOMY	SAREN2/KOMY, McCall Family ET	5
	Rock Outcrop	NA	NA	5
	Glaciers	NA	NA	2
	Water	NA	NA	1
306L	Ledgefork	FEID-ELSP3	FEID-ELSP3, Ledgefork Family ET	90

Map unit	Component	Vegetation	Ecological type	Percent of map unit
	Elwood	FEID-ELSP3-ACNE9	FEID-ELSP3-ACNE9, Elwood Family ET	10
309A	Elwood	FEID-ELSP3-ACNE9	FEID-ELSP3-ACNE9, Elwood Family ET	45
	Como	PIAL/CARO5	PIAL/CARO5, Como Family ET	40
	Elting	ABLA/VASC	ABLA/VASC, Elting Family ET	5
	Rock Outcrop	NA	NA	5
	Targhee	PICOL/CARO5	PICOL/CARO5, Targhee Family ET	5
309L	Ledgefork	ARTRR4/FEID	ARTRR4/FEID, Ledgefork Family ET	30
	Ledgefork	ARTRV2/FEID	ARTRV2/FEID, Ledgefork Family ET	30
	Como	PIAL/CARO5	PIAL/CARO5, Como Family ET	15
	Targhee	PICOL/CARO5	PICOL/CARO5, Targhee Family ET	15
	Elting	ABLA/VASC	ABLA/VASC, Elting Family ET	5
	Rock Outcrop	NA	NA	5
310A	Marosa	ABLA/VASC	ABLA/VASC, Marosa Family ET	55
	Rubble-land	NA	NA	25
	Elting	Warm subalpine fir forests	Warm subalpine fir forests, Elting Family ET	10
	Ledgefork	POTR5/SYORU - Boulder	POTR5/SYORU - Boulder, Ledgefork Family ET	10
310L	Jeru	PIAL/VASC	PIAL/VASC, Jeru Family ET	40
	Elting	ABLA/VASC	ABLA/VASC, Elting Family ET	25
	Rock Outcrop	NA	NA	15
	Rubble-land	NA	NA	10
	Frisco	PIAL/CARO5	PIAL/CARO5, Frisco Family ET	5
	NA	JUPA	JUPA, Oxyaquic Cryorthents Family ET	5
311L	Rock Outcrop	NA	NA	60
	Elting	PIAL/VASC	PIAL/VASC, Elting Family ET	15
	Jeru	PIAL/VASC	PIAL/VASC, Jeru Family ET	15
	Sig	PIAL/VASC	PIAL/VASC, Sig Family ET	10
317L	Ledgefork	POTR5/SYORU - Boulder	POTR5/SYORU - Boulder, Ledgefork Family ET	40

Map unit	Component	Vegetation	Ecological type	Percent of map unit
	Como	PIFL2/JUCOD	PIFL2/JUCOD, Como Family ET	30
	Rock Outcrop	NA	NA	20
	Stecum	PICOL/CARO5	PICOL/CARO5, Stecum Family ET	10
319L	Rock Outcrop	NA	NA	70
	Rubble-land	NA	NA	30
327L	Salt Chuck	PIAL/VASC	PIAL/VASC, Salt Chuck Family ET	45
	Holland Lake	PICOL/JUCOD	PICOL/JUCOD, Holland Lake Family ET	40
	Fluvaquentic Cryaquepts	SALIX/CAREX	SALIX/CAREX, Fluvaquentic Cryaquepts ET	10
	Water	NA	NA	5
327S	Jeru	PIAL/VASC	PIAL/VASC, Jeru Family ET	45
	Swapps	ABLA/VASC	ABLA/VASC, Swapps Family ET	34
	McCall	ABLA/VASC	ABLA/VASC, McCall Family ET	15
	NA	ABLA/RIMO2	ABLA/RIMO2, Cranbay Family ET	5
	Water	NA	NA	1
327W	Bohica	PICOL/SHCA	PICOL/SHCA, Bohica Family ET	85
	Salt Chuck	PIAL/VASC	PIAL/VASC, Salt Chuck Family ET	15
351L	Corbly	ARTRV2/FEID	ARTRV2/FEID, Corbly Family ET 351L	30
	Winspect	ARTRV2/ELSP3	ARTRV2/ELSP3, Winspect Family ET	25
	Rock Outcrop	NA	NA	15
	Bohica	PICOL/SHCA	PICOL/SHCA, Bohica Family ET	10
	Mantador	POTR5/COSE16-ALVIS	POTR5/COSE16-ALVIS, Mantador Family ET	10
	Yourame	PSMEG/ACGL	PSMEG/ACGL, Yourame Family ET	10
	NA	ELSP3	ELSP3, Wabek Family ET	5
402L	Bullflat	POTR5/GEVI2	POTR5/GEVI2, Bullflat Family ET	50
	Caryville	POTR5/COSE16-ALVIS	POTR5/COSE16-ALVIS, Caryville Family ET	50

Appendix 5: Narrative Soil Map Unit Descriptions

Description

The following section provides narrative descriptions of the soil map units of the Wind River Range portion of the Shoshone National Forest National Cooperative Soil Survey. Table 5-1 presents the areal extent of soil map units within the study area.

102–Cryaquepts, Cryaquolls, and Cryofluvents soils, 0 to 3% slopes, volcanic alluvium

This map unit encompasses 26.1 ha in the northern study area and is located in the Dry Mid-Elevation Sedimentary Mountains and Granitic Subalpine Zone ecoregions (Chapman and others 2004). This map unit encompasses an undifferentiated group, including wetland soils formed from granitic alluvium on floodplains. There was insufficient data to assign ecotypes to this map unit.

260–Frisco-Taglake-Helmville Families, Complex, 5 to 40% slopes

This map unit encompasses 1334.7 ha in the northern study area and is located in the Dry Mid-Elevation Sedimentary Mountains and Granitic Subalpine Zone ecoregions (Chapman and others 2004). This map unit is a complex of soils derived from granitic and gneissic till on moraines and soils derived from mixed sedimentary colluvium. Vegetation is typically conifer forest. There was insufficient data to assign ecotypes to this map unit.

266–Sigbird-Guffey-Geertsen Families, Complex, 15 to 40% slopes

This map unit encompasses 146.7 ha in the northern boundary of the northern study area and is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004).This map unit includes a complex of soils derived from acidic volcanic breccia colluvium and mixed sedimentary colluvium on mountain slopes. There was insufficient data to assign ecotypes to this map unit.

268–Thornburgh-Goosepeak-Cundiyo FamiliesComplex, Complex, 15 to 50% slopes

This map unit encompasses 2398.6 ha in the northern study area and is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). This map unit is a complex soils derived from limestone, sandstone, and shale colluvium. This map unit includes the Bighorn Dolomite, Madison Limestone, and Gallatin Limestone Formations. This map unit includes north- and east-facing limestone and dolomite backslopes, along steep canyon walls, and as narrow corridors along headwater drainages on northerly exposures. The vegetation is Douglas-fir and subalpine fir forests. This map unit is similar to unit 43L. There was insufficient data to assign ecotypes to this map unit.

Table 5-1—Areal extent in hectares of soil map units within the study area, including whether or not ecological types were assigned to each map unit, if the map unit is a join unit from an adjacent soil survey, and if the map unit exists outside the study area in the northern Shoshone National Forest (SNF), ecological type classification of the eastern slope of the Wind River Range, Shoshone National Forest, Wyoming.

Map unit	Area within study area (ha)	Percent of study area	Ecological types assigned to map unit?	Join unit from adjacent survey?[1]	Does the map unit extend outside the study area into the northern SNF?[2]
102	26.1	0.01%	n	—	y
260	1,334.7	0.70%	n	—	y
266	146.7	0.08%	n	—	y
268	2,398.6	1.26%	n	—	y
302	1,711.4	0.90%	y	—	y
311	782.4	0.41%	y	—	y

Table 5-1—*Continued.*

Map unit	Area within study area (ha)	Percent of study area	Ecological types assigned to map unit?	Join unit from adjacent survey?[1]	Does the map unit extend outside the study area into the northern SNF?[2]
323	57.6	0.03%	n	—	y
327	79.9	0.04%	n	—	y
350	2,228.9	1.17%	n	—	y
402	1.3	0.00%	y	—	y
505	3,197.3	1.67%	n	—	y
12L	7,482.2	3.92%	y	—	n
15L	4,366.0	2.29%	y	—	y
302L	7,078.7	3.71%	y	—	y
304L	36,371.0	19.04%	y	—	n
306L	64.8	0.03%	y	—	n
309A	3,252.3	1.70%	y	—	n
309L	5,705.9	2.99%	y	—	n
310A	2,207.0	1.16%	y	—	n
310L	12,312.3	6.45%	y	—	n
311L	15,187.8	7.95%	y	—	n
317L	1,247.1	0.65%	y	—	n
319L	21,367.5	11.19%	y	—	n
327L	3,166.8	1.66%	y	—	n
327S	26,089.4	13.66%	y	—	n
327W	2,686.9	1.41%	y	—	n
351L	1,454.9	0.76%	y	—	n
402L	656.5	0.34%	y	—	n
43L	5,436.6	2.85%	y	—	n
43LF	5,866.2	3.07%	y	—	n
44L	464.9	0.24%	y	—	n
GLAC	4,029.7	2.11%	n	—	y
IH2O	4.9	0.00%	n	—	y
W	3,774.3	1.98%	n	—	y
106D	1,478.4	0.77%	y	D	n
107D	722.4	0.38%	n	D	n
125D	162.1	0.08%	n	D	n
130D	947.0	0.50%	n	D	y
147D	9.8	0.01%	n	D	n
149D	3.2	0.00%	n	D	y
162D	78.9	0.04%	n	D	n
163D	76.1	0.04%	n	D	n
166D	1,627.5	0.85%	y	D	n
168D	15.8	0.01%	n	D	y
173D	435.0	0.23%	n	D	y
180D	165.3	0.09%	n	D	n
193D	10.5	0.01%	n	D	y
194D	18.1	0.01%	n	D	y
200D	104.1	0.05%	n	D	y
209D	59.0	0.03%	n	D	y
211D	25.3	0.01%	n	D	n
219D	563.2	0.29%	n	D	y
221D	43.9	0.02%	n	D	y
229D	491.3	0.26%	n	D	n
1701BT	23.6	0.01%	n	BT	n
1801BT	165.3	0.09%	n	BT	n
575T	110.6	0.06%	n	BT	n
7602BT	142.8	0.07%	n	BT	n
7621BT	596.9	0.31%	n	BT	n
7643BT	702.7	0.37%	n	BT	n
8004BT	3.1	0.00%	n	BT	n
Total	191,020.5	100.00%			

[1] Indicates that the unit is not a join unit from an adjacent soil survey area; D = Map unit is a join unit from Fremont County, Wyoming, East Part and Dubois Area survey area (WY713); BT = Map unit is a join unit from Bridger National Forest, Wyoming, Eastern Part survey area (WY662).

[2] This field indicates whether or not a soil map unit extends outside the study area boundary into the northern Shoshone National Forest; hence, areas reported above will differ from total area within the Shoshone National Forest. For complete spatial and tabular soil map unit data, please refer to USDA, NRCS (2008).

311–Rock outcrop-Dystrocryepts-Enentah Family Complex, 15 to 45% slopes

This map unit encompasses 782.4 ha in the northwest corner of the northern study area and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). This map unit encompasses a complex of rock outcrop and soils derived from granite bedrock and granitic till. Vegetation is rocky barrens and white park pine forests and woodlands with scattered subalpine grasslands. This map unit is similar to unit 311L.

323–Broad Canyon Family-Typic Argicryolls Complex, 0 to 10% slopes

This map unit encompasses 57.6 ha in the northwest corner of the northern study area and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). This map unit encompasses a complex soils derived from granitic till. Vegetation is typically subalpine grassland. There was insufficient data to assign ecotypes to this map unit.

327–Enentah-Firada Families, Complex, 15 to 35% slopes

This map unit encompasses 79.9 ha in the northwest corner of the northern study area and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). This map unit includes a complex of soils derived from granitic till on moraines in mountain valleys. Vegetation is subalpine forest. This unit is similar to unit 327S. There was insufficient data to assign ecotypes to this map unit.

350–Frisco-Enentah Families, Complex, 5 to 30% slopes

This map unit encompasses 2228.9 ha in the northwest corner of the northern study area and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). This map unit encompasses a complex soils derived from granitic till. Vegetation is subalpine forest. There was insufficient data to assign ecotypes to this unit.

505–Cheadle-Sawpit-Gany Families, Complex, 15 to 35% slopes

This map unit encompasses 3197.3 ha in the northern study area including Whiskey and Arrow Mountains and is located in the Alpine Zone and Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). This map unit is a complex soils derived from limestone, sandstone, and shale residuum and colluvium on mountain slopes and summits. Vegetation includes rocky barrens, alpine turf and fellfield, and subalpine woodlands and shrublands. There was insufficient data to assign ecotypes to this unit.

12L–Lolo Family-Rock outcrop-Shawmut Family Complex, 15 to 60% slopes

This map unit encompasses 7482.2 ha and is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). This unit occurs in the northern study area from Warm Spring and Bald Mountain southeast to Arrow Mountain, and in the southern study area from Fairfield Hill southeast to Limestone Mountain. An isolated occurrence is directly northeast of Dickinson Park. This unit includes the Bighorn Dolomite, Madison Limestone, and Gallatin Limestone Formations. The Darby Formation is also included in the northern extent. This map unit includes south- and west-facing limestone and dolomite summits, shoulders, ridgelines, vertical cliff faces, and limited amounts of northeast-facing limestone and dolomite dip slopes. Vegetation includes mixed Douglas-fir/limber pine forests on northerly exposures and a mosaic of limber pine woodlands and mountain big sagebrush on southerly exposures.

15L–Winspect-Kiev-Bigsheep Families Complex, 15 to 40% slopes

This map unit encompasses 4405.1 ha, including 39.2 ha that occur just north and outside of the northern boundary of the northern study area. This map unit is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). In the southern study area, it occurs from Fairfield Hill southeast to Limestone Mountain. An isolated occurrence is directly northeast of Dickinson Park. Geologic units include the Gros Ventre and Amsden Formations. Small amounts of the Phosphoria Formation occur along the eastern extent in the southern Wind River Range. In the north, limited areas of the Madison Limestone Formation are also included. This map unit includes south-, west-, and northwest-facing Gros Ventre and Amsden scarp slopes with gently rounded summits, and northeast-facing Phosphoria dip-slopes. Vegetation includes mountain big sagebrush/bluebunch wheatgrass, mountain big sagebrush/Idaho fescue, Wyoming three-tip sagebrush/bluebunch wheatgrass, Wyoming three-tip sagebrush/Idaho fescue habitat types, Idaho fescue and bluebunch wheatgrass grasslands, scattered limber pine woodlands, and isolated quaking aspen stands located in topographic depressions.

43L–Cloud Peak-Redfist-Frisco Families Complex, 15 to 60% slopes

This map unit encompasses 5436.6 ha and is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). It occurs in the northern study area, west and south of Dubois from Bald Mountain southeast to Arrow Mountain. In the southern study area, map unit 43L occurs from Fairfield Hill, southeast to Limestone Mountain. An isolated occurrence occurs directly northeast of Dickinson Park. This map unit includes the Bighorn Dolomite, Madison Limestone, and Gallatin Limestone Formations. The Darby Formation is also included in the northern extent. It also includes north- and east-facing limestone and dolomite backslopes, along steep canyon walls, and as narrow corridors along headwater drainages on northerly exposures. The vegetation is Douglas-fir and subalpine fir forests. This map unit is similar to unit 268.

43LF–Como-Agneston Families-Rock outcrop Complex, 7 to 40% slopes

This map unit encompasses 5866.2 ha and is located in the Dry Mid-Elevation Sedimentary Mountains ecoregion (Chapman and others 2004). It occurs in the southern study area from just northeast of Dickinson Park, southeast to Beaver Creek. This map unit includes northeast-facing dip slopes of Flathead and Tensleep sandstone. The vegetation is lodgepole pine and subalpine fir forests, and whitebark pine forests at the highest elevations.

44L–Bullflat-Ledgefork Families Complex, 7 to 40% slopes

This map unit encompasses 464.9 ha and is located in the southeastern Wind River Range, including the Dry Mid-Elevation Sedimentary Mountains and the Granitic Subalpine Zone ecoregions (Chapman and others 2004). In the Dry Mid-elevation Sedimentary Mountains ecoregion, 239 ha occur on slumps, landslide deposits, in topographic depressions, and along riparian zones from just north of Fairfield Hill southeast to Beaver Creek. Parent materials in the Dry Mid-elevation Sedimentary Mountains ecoregion were mixed calcareous colluvium at upland sites or sandy alluvium along streams. In the Granitic Subalpine Zone ecoregion, 213 ha occur on seepy hillsides, bouldery slopes, topographic depressions, and along riparian zones. Parent materials in the Granitic Subalpine Zone are granodiorite or quartz monzonite colluvium or glacial till at upland sites, and mixed granitic alluvium along streams. The vegetation is quaking aspen forests.

106D–Ansel-Wix Family Complex, 5 to 45% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 1478.4 ha in the South Pass Granite-Greenstone Belt. This unit includes the Goldman Meadows and Diamond Springs Formations, the Round Top Mountain Greenstone, and the Gneiss Complex. It also includes sheltered slopes on rolling hills and moderately steep mountain slopes and summits. Vegetation includes lodgepole pine and Douglas-fir forests and scattered quaking aspen stands.

107D–Ansel-Rock outcrop Complex, 5 to 25% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 722.4 ha in the extreme southeastern portion of the southern study area. This map unit includes a complex of fan aprons, hills, and rock outcrop in granodiorite of the Louis Lake Pluton. Vegetation includes a mosaic of lodgepole pine and Douglas-fir forests, and mountain big sagebrush/Idaho fescue rangelands.

125D – Brownsto, very bouldery-Anamac Family-Brownsto Complex, 1 to 50 % slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). This unit is approximately equivalent to map unit 351L on the Shoshone National Forest soil survey. It encompasses 162.1 ha in the northeastern portion of the northern study area near Torrey Lake. This map unit is a complex of soils derived from mixed sedimentary and granitic glaciofluvial outwash and alluvium in basins and on hills and terraces. Vegetation is primarily bluebunch wheatgrass and Great Basin wildrye.

130D–Cloud Peak-Farlow Complex, 10 to 30% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). This unit is approximately equivalent to map units 12L and 43L on the Shoshone National Forest soil survey. It encompasses 947.0 ha in the northeastern portion of the northern study area. This map unit is a complex of soils derived from limestone residuum and colluvium on mountain slopes and valley sides.

147D–Forelle-Luhon loams, 1 to 10% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 9.8 ha in the northeastern portion of the northern study area.

149D–Fornor-Decross Complex, 1 to 30% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 3.2 ha in the northeastern portion of the northern study area.

162D–Hoodle-Rock outcrop Complex, 1 to 8% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 78.9 ha in the extreme southeastern portion of the Wind River Range. This map unit includes a complex of alluvial terraces, rocky knobs, and summits of hills in granodiorite of the Louis Lake Pluton. Vegetation on the alluvial terraces is primarily bluebunch wheatgrass.

163D–Hoodle-Gelkie association, 2 to 15% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 76.1 ha in the northeastern portion of the northern study area. This map unit represents an association of soils derived from sandstone and granitic alluvium on gentle slopes. Vegetation is characterized by bluebunch and western wheatgrasses.

166D–Irigul-Midelight-Rock outcrop Association, 1 to 15% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 1627.5 ha in the South Pass Granite-Greenstone Belt. This map unit includes Goldman Meadows and Diamond Springs Formations, Round Top Mountain Greenstone, and Gneiss Complex. It also includes exposed slopes on gently rolling hills and moderately steep mountain slopes and summits. Vegetation includes mountain big sagebrush, low sagebrush, and Idaho fescue.

168D–Lander-Meadowcreek Family, Complex, 0 to 3% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 15.8 ha in the northeastern portion of the northern study area. This map unit is a complex of soils derived from mixed granitic and sedimentary alluvium in basins and on floodplains. Vegetation is characterized by willows and tufted hairgrass.

173D–Farlow Family-Nathrop Family-Starman Complex, 10 to 50% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). It encompasses 435.0 ha in the northeastern portion of the northern study area. This unit is approximately equivalent to map units 15L on the Shoshone National Forest soil survey. This map unit is a complex of soils derived from limestone and sandstone residuum and colluvium on mountain slopes and valley sides. Vegetation is typified by bluebunch wheatgrass and Idaho fescue.

180D–Pensore-Rock outcrop Complex, 5 to 50% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). It encompasses 165.3 ha in the northeastern portion of the northern study area. There were no equivalent map units on the Shoshone National Forest soil survey. This map unit is a complex of rock outcrop and soils derived from limestone residuum on hillsides. Vegetation is dominated by bluebunch wheatgrass.

193D–Rockinchair-Rock outcrop-Sinkson Complex, 2 to 40% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). It encompasses 10.5 ha in the northeastern portion of the northern study area. There were no equivalent map units on the Shoshone National Forest soil survey. This map unit is a complex of rock outcrop and soils derived from sandstone and shale residuum and colluvium on hillslopes and in basins, respectively. Vegetation is typically bluebunch wheatgrass and sagebrush.

194D–Rockinchair-Sinkson Complex, 1 to 15% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). It encompasses 18.1 ha in the northeastern portion of the northern study area. There were no equivalent map units on the Shoshone National Forest soil survey. This map unit is a complex of rock outcrop and soils derived from sandstone and shale residuum and colluvium on hillslopes and in basins, respectively. Vegetation is typically bluebunch and western wheatgrasses and sagebrush.

200D–Roxal-Rock outcrop Complex, 20 to 65% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 104.1 ha in the northeastern portion of the northern study area. This map unit is a complex of rock outcrop and soils derived from sandstone and shale residuum. Vegetation is characterized by Idaho and spike fescue, antelope bitterbrush, and sagebrush.

209D–Starman-Rock outcrop-Woosley Complex, 10 to 40% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 59.0 ha in the northeastern portion of the northern study area. This map unit is a complex of rock outcrop and soils derived from limestone residuum on mountain slopes and mixed sedimentary alluvium on alluvial fans. Vegetation is characterized by Idaho and spike fescue, bluebunch wheatgrass, and sagebrush.

211D–Thermopolis-Sinkson association, 3 to 30% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 25.3 ha in the northeastern portion of the northern study area. This map unit is an association of soils derived from siltstone residuum on ridges and mixed sandstone and siltstone alluvium on fan aprons. Vegetation is characterized by bluebunch and western wheatgrass and sagebrush.

219D–Venapass-Silas Complex, 0 to 6% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). This join unit is approximately equivalent to map unit 302 and 302L on the Shoshone National Forest soil survey. Map unit 219D encompasses 563.2 ha spanning from the South Pass Granite-Greenstone Belt east to the Continental Divide, and another 181 ha in the northern Wind River Range and southern Absaroka Range to the northwest of Dubois, Wyoming. It includes floodplains and terraces composed of alluvium derived from a variety of igneous and metamorphic materials. Vegetation includes willow thickets, sedges, and moist grasses.

221D–Woosley-Decross-Starman association, 2 to 20% slopes

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 43.9 ha in the northeastern portion of the northern study area. This map unit is an association of soils derived from limestone residuum and colluvium on mountain slopes and hills. Vegetation is typified by Idaho fescue and sagebrush.

229D–Dumps, mine

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of Fremont County (USDA, NRCS 2007c). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 491.3 ha in the southeastern portion of the southern study area. This map unit includes an iron strip mine near Iron Mountain.

302/302L–Moose River-Elvick Families Complex, 3 to 25% slopes

These map units encompasses a total of 12,398 ha and are located in the Alpine Zone and Granitic Subalpine Zone ecoregions (Chapman and others 2004), 8790.1 ha in the northern and southern study areas. They include riparian areas and wetlands that feature soils derived from mixed granitic alluvium. Vegetation includes forested alluvial terraces, willow thickets, and moist/wet sedge-grassland meadows and floodplains.

304L–Agneston-McCall Families-Rubble land Complex, 15 to 60% slopes

This map unit encompasses 36,3710 ha and is located in the Alpine Zone ecoregion (Chapman and others 2004). It occurs from Shale Mountain and Ram Flat in the northwest to Christina Pass in the southeast, and includes all land above timberline that is not dominated by steep, cliffy rock outcrop. This map unit includes remnant summit erosion surfaces, alpine plateaus and ridges, mountain summits, and glacial cirques. In the southeastern Wind River Range, south of the Middle Fork Popo Agie drainage, bedrock is Louis Lake Granodiorite. North of the Middle Fork Popo Agie drainage, bedrock is quartz monzonite. In the northern Wind River Range, parent material is quartz monzonite, gneiss, and/or migmatite. Vegetation includes alpine turf, alpine fellfields, krummholz, and alpine willows.

306L–Ledgefork Family, 7 to 40% slopes

This map unit encompasses 64.8 ha and is located in the southern study area in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It is located at Dickinson Park to the southwest of Black Mountain. This map unit occurs on a lateral moraine of Bull Lake age and is composed of compacted granitic glacial till (Pearson and others 1973). Glacial erratics are common. Vegetation includes Idaho fescue grasslands.

309A–Elwood-Como Families Complex, 7 to 40% slopes

This map unit encompasses 3252.3 ha and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs primarily around Blue Ridge and the headwaters of Sawmill and Canyon Creeks. Small areas occur to the southwest of Louis Lake (348 ha) and at Dickinson Park (297 ha). On Blue Ridge, the headwaters of Sawmill and Canyon Creeks, and in the area southwest of Louis Lake, bedrock is Louis Lake Granodiorite. At Dickinson Park, bedrock is quartz monzonite. Vegetation is park-forest vegetation, including a mosaic of whitebark pine forests and Idaho fescue grasslands on south-facing slopes, and subalpine fir forests on north-facing slopes.

309L–Ledgefork-Como-Targhee Families Complex, 7 to 40% slopes

This map unit encompasses 5705.9 ha and is located in the southern study area in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs from just south of Bayer Mountain in the north to Little Pine Creek in the southwest. This map unit includes a series of intersecting diabasic gabbro dikes that bisect the Louis Lake Granodiorite (Bayley and others 1973). Streams in this area occur in narrow valleys separated by the parallel dikes, forming a distinct trellis pattern, where the less resistant Louis Lake Granodiorite alternates with the resistant diabasic gabbro of the dikes (Chernicoff and others 1997). Vegetation is Wyoming three-tip sagebrush/Idaho fescue on south-facing dike upper backslopes and shoulders, mountain big sagebrush/Idaho fescue on south-facing dikes, lower backslopes and footslopes, and whitebark pine or subalpine fir forests on north-facing dike slopes.

310A–Marosa Family-Rubble land Complex, 7 to 60% slopes

This map unit encompasses 2207.0 ha and is located in the southern study area in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs primarily around Louis Lake in the southeastern Wind River Range. A small area (184 ha) occurs to the east of Dickinson Park. This map unit includes mountain slopes and mountain summits. Parent material is granodiorite near Louis Lake and quartz monzonite east of Dickinson Park. Vegetation is subalpine fir, whitebark pine, and scattered aspen forests. Extensive talus slopes are common.

310L–Jeru-Elting Families-Rock outcrop Complex, 7 to 60% slopes

This map unit encompasses 12,312.3 ha and is located in the Granitic Subalpine Zone (Chapman and others 2004). It occurs in the southern study area from the South Fork Little Wind River and Dickinson Park in the north, southeast to Christina Lake. Included are forested mountain slopes that extend from above till-mantled glacial valleys to timberline and the forested lower portion of glacial cirques. South of the Middle Fork Popo Agie drainage, parent material is primarily granodiorite residuum, colluvium, or glacial till. North of the Middle Fork Popo Agie drainage, parent material is primarily quartz monzonite residuum, colluvium, or glacial till. This map unit is characterized by whitebark pine and subalpine fir forests and scattered rock outcrop. In the lower portion of glacial cirques, and near timberline, vegetation is a mosaic of scattered stands of whitebark pine, and alpine grasslands.

311L–Rock outcrop-Elting-Jeru Families Complex, 15 to 60% slopes

This map unit encompasses 15,187.8 ha and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs southwest of Dubois, WY, in the upper Jakeys Fork drainage in the northern study area south to Stough Creek Basin in the southern study area. This map unit includes gently rounded, glacially scoured mountains dominated by moderately steep, rock outcrop. In the southern study area, south of the Middle Fork Popo Agie drainage, bedrock is Louis Lake Granodiorite. North of the Middle Fork Popo Agie drainage, bedrock is quartz monzonite. In the northern study area, parent material is quartz monzonite, gneiss, and/or migmatite. This map unit is largely composed of rock outcrop with scattered whitebark pine forests. This map unit is similar to unit 311.

317L–Ledgefork-Como Families-Rock outcrop Complex, 7 to 40% slopes

This map unit encompasses 1247.1 ha and is located in the southern study area within the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs northeast of Frye Lake and near South Pass. This map unit includes mountain slopes, ridges, and rock outcrop formed from foliated granodiorite of the Louis Lake Pluton (Bayley and others 1973). The vegetation includes open Douglas-fir and limber pine forests, small patches of mountain big sagebrush, and large, isolated quaking aspen stands at footslope positions and on boulder-strewn slopes.

319L–Rock outcrop-Rubble land Complex

This map unit encompasses 21,367.5 ha and is located in the Alpine Zone ecoregion (Chapman and others 2004). It occurs from Shale Mountain and Ram Flat in the northwest to Christina Pass in the south. Map unit 319L includes all land above timberline that is dominated by steep, cliffy rock outcrop. In the southern study area, south of the Middle Fork Popo Agie drainage, bedrock is Louis Lake Granodiorite. North of the Middle Fork Popo Agie drainage, bedrock is quartz monzonite. In the northern study area, parent material is quartz monzonite, gneiss, and/or migmatite. Vegetation is sparse or non-existent in this map unit.

327L–Salt Chuck-Holland Lake Families Complex, 3 to 25% slopes

This map unit encompasses 3166.8 ha and is located in the Granitic Subalpine Zone ecoregion in the southern study area (Chapman and others 2004). It encompasses glacial moraines that extend from Christina Lake and Atlantic and Silas Canyons in the west to Louis Lake and Maxon Basin on the eastern periphery. This map unit is bound on the north by Blue Ridge. It includes granodiorite glacial till and features classic kettle and kame glacial topography. Numerous small kettle lakes occur scattered across the map unit. The vegetation is lodgepole pine forests at lower elevations and whitebark pine forests at upper elevations.

327S–Jeru-Swapps-McCall Families Complex, 7 to 40% slopes

This map unit encompasses 26,089.4 ha and is located in the Granitic Subalpine Zone ecoregion (Chapman and others 2004). It occurs in the northern study area along glacial valleys from the South Fork of Warm Spring Creek and Simpson Lake, southeast to the Middle Fork Bull Lake Creek. In the southern study area, it occurs along glacial valleys from the South Fork Little Wind River southeast to the Middle Fork Popo Agie River and the headwaters of Roaring Fork Creek. Throughout the study area, this map unit occurs on extensive lateral glacial moraines in glacially carved valleys. In the southern study area, south of the Middle Fork Popo Agie drainage, parent material is primarily granodiorite glacial till. North of the Middle Fork Popo Agie drainage, parent material is primarily quartz monzonite glacial till. In the northern study area, parent material is mixed quartz monzonite, gneiss, and migmatite glacial till. Vegetation is subalpine fir and whitebark pine forests.

327W–Bohica-Salt Chuck Families Complex, 7 to 40% slopes

This map unit encompasses 2686.9 ha and is located in the southern study area within the Granitic Subalpine Zone ecoregion (Chapman and others 2004). A small portion (~140 ha) extends down along Sawmill Creek into the Dry Mid-Elevation Sedimentary Mountains ecoregion. This map unit occurs in the north from Worthen Meadows and Frye Lake, south to the headwaters of Sawmill and Burnt Gulch Creek, and east along Sawmill Creek to just downstream of its junction with Townsend Creek. It includes extensive granitic glacial moraines of Pinedale age. Vegetation includes lodgepole pine, whitebark pine, and subalpine fir forest and scattered Idaho fescue parkland.

351L–Corbly-Winspect Families-Rock outcrop Complex, 7 to 60% slopes

This map unit encompasses 1454.9 ha and is located in the southern study area within the Dry Mid-Elevation Sedimentary Mountains and the Granitic Subalpine Zone ecoregions (Chapman and others 2004). It encompasses the Sinks Canyon moraine and occurs along the lower reaches of the Middle Popo Agie River from roughly 6 km upstream of Popo Agie Falls downstream to the Shoshone National Forest Boundary. The upper portion is bounded on the north and south by the canyon rim. The lower portion is bounded on the north by outcrops of the Gallatin and Bighorn Formations and terminates to the south between 2200 and 2300 m elevation. Near the eastern extent of this map unit, 126 ha occur above the canyon rim along a section of the ridge that runs northeast from Fossil Hill near Deer Spring. Along the upper portion, soils are derived from granitic glacial till, while the soils of the lower portion are derived from a thin veneer of Bighorn and Gallatin colluvium over granitic glacial till. Vegetation includes Utah juniper, mountain big sagebrush, bluebunch wheatgrass, and Idaho fescue on southerly exposures, and lodgepole pine, Douglas-fir, and quaking aspen groves on northerly exposures.

402/402L–Bullflat-Caryville Families Complex, 7 to 25% slopes

These map units encompasses 657.8 ha and are located in the Dry Mid-elevation Sedimentary Mountains ecoregion (Chapman and others 2004). These map units include riparian areas and wetlands that feature soils derived from mixed sedimentary alluvium. Vegetation includes quaking aspen forests, willow thickets, and moist/wet sedge-grassland meadows and floodplains.

575T–Lithic Cryorthents-Mollic Haplocryalfs-Typic Cryorthents Complex, 10 to 50% slopes

This is a join map unit, and there were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 110.6 ha on the northwest boundary of the northern study area.

1701BT–Alpine Cirques, Rock outcrop-Tundra-Willow Complex

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). This unit is approximately equivalent to map unit 304L on the Shoshone National Forest soil survey, and it encompasses 23.6 ha along the Continental Divide near Sweetwater Gap. It includes soils derived from granitic residuum, colluvium, and glacial till and soils located in alpine glacial cirques. Vegetation includes willows and alpine tundra.

1801BT–Alpine Ridges, Rubble Land-Tundra Complex

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). This join unit would be included in map unit 304L on the Shoshone National Forest soil survey. This map unit encompasses 165.3 ha and includes rubble land and soils derived from granitic residuum and colluvium. Vegetation is typically sparse, but may include alpine turf and fellfield.

7602BT–Southeast Mountains sideslopes, Rock outcrop-Subalpine fir Complex

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). This join unit would be included in map units 310L or 327S on the Shoshone National Forest soil survey. It encompasses 142.8 ha near Sweetwater Gap and includes till mantled mountain slopes, snow avalanche slopes, and rocky knobs along glacial mountain valleys. Rock outcrops are of granite gneiss, granodiorite, and quartz diorite. Vegetation includes subalpine fir/grouse whortleberry forests.

7621BT–Southeast Mountains sideslopes, Big sagebrush–Douglas-fir–Rock outcrop Complex

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). There were no equivalent map units on the Shoshone National Forest soil survey. It encompasses 596.9 ha in the extreme southeastern portion of the Wind River Range. This map unit includes benches and sideslopes of smooth and broken mountain slopes. Rock outcrops are of granodiorite. Vegetation is a mosaic of Douglas-fir forests and mountain big sagebrush/Idaho fescue rangelands.

7643BT–Southeast Mountains sideslopes, Subalpine fir Complex

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). This join unit is approximately equivalent to map unit 310A on the Shoshone National Forest soil survey. It encompasses 702.7 ha near Rennecker and Pabst Peaks in the extreme southeastern portion of the Wind River Range. This unit includes backslopes and benches of smooth mountain slopes in granodiorite bedrock. Vegetation tends toward the warmer end of the subalpine fir zone, including the subalpine fir/heartleaf arnica and subalpine fir/Oregon grape habitat types.

8004BT–Rubble Land

This is a join map unit that was originally developed for the adjacent soil survey of the eastern part of the Bridger-Teton National Forest (Svalberg and others 1997). This join unit would be included in map units 319L or 304L on the Shoshone National Forest soil survey. It encompasses 3.1 ha along the Continental Divide near Sweetwater Gap and is composed of landslide deposits, avalanche debris, talus, scree slopes, and debris fans on mountain slopes, ridges, and peaks. Bedrock geology includes granodiorite or quartz monzonite. Alpine tundra vegetation occurs in small, isolated patches.

GLAC–Glaciers

This map unit encompasses 4029.7 ha and is located in the primarily along the eastern boundary of the northern study area, including the Alpine Zone ecoregion (Chapman and others 2004). It also encompasses glaciers and permanent snow fields in glacial cirques.

IH2O–Water, Aquepts, and Aquolls soils, 0 to 3% slopes

This map unit encompasses 4.9 ha and is located in primarily the southern study area. This unit encompasses small ponds and lake margins, including water and flooded soils.

W–Water

This map unit encompasses 3774.3 ha and is located throughout the north and south study area, primarily in the Alpine Zone Granitic Subalpine Zone ecoregion (Chapman and others 2004). This unit includes water in lakes, ponds, and reservoirs.

Appendix 6: Additional Species Descriptions

Description

The following provides ecology and management information for 13 common plant species found along the eastern slope of the Wind River Range. This information supplements the principal species descriptions found in the "Ecological Type Descriptions" section.

Tree Species

Engelmann spruce

Picea engelmannii Parry ex Engelm.

Engelmann spruce occurs in British Columbia south of approximately 55º Latitude from the eastern slope of Coast Range eastward into the Rocky Mountains of southwestern Alberta (Thompson and others 1999). In southern British Columbia and Alberta, the geographic distribution follows two separate paths. One path follows the eastern slope of the Cascade Ranges in Washington and Oregon south to Mount Shasta in northern California. The second path follows the Rocky Mountains through northern and central Idaho, western Montana, and northwestern Wyoming south through Utah, western Colorado, and northern New Mexico. Disjunct populations occur in the Blue Mountains of northeastern Oregon, Bighorn and Laramie Mountains of Wyoming, and scattered mountain ranges in northeastern Nevada, northeastern and southern Arizona, and southern New Mexico.

Engelmann spruce is a common, cold hardy conifer in subalpine and timberline forests. Average annual temperature in Engelmann spruce forests in the northern and central Rocky Mountains ranges between -1 and 2 ºC (Alexander and Shepperd 1990). The range of average January and July temperatures in Engelmann spruce forests are -12 to -7 and 4 to 13 ºC, respectively. Annual precipitation, most of which is deposited in the form of snow (avg. 381–889+ cm), ranges between 610 and 1,400 mm. In British Columbia and Alberta, Engelmann spruce is most common between 762 and 1,829 m. In the Rocky Mountains of Idaho, Montana, and eastern Washington and Oregon, Engelmann spruce is most common between 1,524 and 1,829 m, above which it is a minor forest component, and below which it is confined to cold air drainages, frost pockets, and moist microsites. In Wyoming, Utah, and Colorado, Engelmann spruce occurs between 2,743 and 3,353 m but may occur as low as 2,438 in cold air drainages and frost pockets. At the southern end of its range, in Arizona and New Mexico, it occurs between 2,438 and 3,658 m.

Engelmann spruce occurs on a variety of substrates; however, in the central Rocky Mountains, contiguous, climax stands may be more common on basic volcanic rocks (especially andesite) and calcareous sedimentary rocks (Steele and others 1983). Engelmann spruce has been reported to occur on limestone, calcareous shale and sandstone, andesite, basalt, quartz monzonite, rhyolite, argillite, quartzite, gneiss, granite, granodiorite, breccia, tuff, schist, siltstone, peridotite, glacial till, colluvium, and alluvium (Pfister and others 1977; Steele and others 1981, 1983; Youngblood and Mauk 1985; Svalberg and others 1997; Johnston and others 2001; Johnson 2004). Regardless of parent material, Engelmann spruce is most productive on moderately deep and deep, well drained, loamy sands, silt loams, or clay loams (Alexander and Shepperd 1990). On coarser soils, developed from glacial till or sandy alluvium, direct access to the water table is more important than the physical properties of the soils. Engelmann spruce is tolerant of soil saturation and commonly produces pure, climax stands in wet meadows and springs and on floodplains, streambanks, and seepy slopes (Wells 2006). Soils in riparian zones and wetlands may include peat, organic-rich loams, silt loams, and sandy loams with seasonal surface flooding, and extended periods of soil saturation within the rooting zone of Engelmann spruce.

Engelmann spruce is intolerant of high temperatures and drought and is moderately shade tolerant (Alexander and Shepperd 1990). In the Rocky Mountains of northern Idaho and northwestern Montana, regions that experience a maritime influence, Engelmann spruce is seral to grand fir, mountain hemlock, and western red cedar (Steele and others 1983). In the Rocky Mountains outside of maritime influence, Engelmann spruce is typically seral to subalpine fir, a more shade-tolerant species. However, Engelmann spruce typically outlives subalpine fir and persists to climax, sharing dominance with subalpine fir (Uchytil 1991b). Engelmann spruce has higher tolerance to soil saturation than subalpine fir, and at wetter sites, Engelmann spruce forms pure climax stands.

Engelmann spruce is one of the largest native, high-elevation conifers in North America (Uchytil 1991b). Mature trees average 14 to 40 m in height and 38 to 76 cm in diameter but may reach sizes in excess of 49 m tall and 102 cm in diameter. Engelmann spruce is also long-lived, commonly living between 350 and 600 years. It features a narrow, pyramid-shaped crown with short, compact branches. Dead lower limbs are usually persistent throughout the lifespan of an individual.

Engelmann spruce is monoecious and features male cones on lower crown and female cones near the end of branches on the upper crown (Alexander and Shepperd 1990). Seed production begins at 25 to 40 years of age but is greatest between 150 to 250 years of age. Pollen is wind disseminated between late May and early July depending on elevation. The female cones are down turned, tawny to light brown in color, and 2.5 to 6.3 cm when they ripen in August to early September. Seeds are wind dispersed, and cones remain intact following seed drop. Engelmann spruce seeds require mineral soil seedbeds for successful germination (Uchytil 1991b). Germination and successful seedling development are favored by 40 to 60 percent of full shade (Alexander and Shepperd 1990). Seedlings are extremely susceptible to drought, high temperatures, and intense solar radiation up to five years of age. Adequate soil moisture and partial shade are essential components in the successful regeneration of Engelmann spruce. The species may reproduce by layering; however, compared to subalpine fir, layering is of minor importance to Engelmann spruce as a reproduction method in close-canopy stands.

Engelmann spruce is very sensitive to fire due to (1) thin, resinous bark; (2) shallow roots; (3) persistent, low growing, lichen covered branches; (4) a tendency to form dense stands; and (5) moderately flammable foliage (Uchytil 1991b). Fuel structure in the subalpine forests where Engelmann spruce occurs, including abundant fine needle and twig litter, and persistent low-growing branches promotes large stand replacing burns. Fires typically burn slowly near ground level at first until the flames reach the low growing branches and travel into the crown. Fire return interval in Engelmann spruce stands is typically greater than 150 years. Following clear-cutting of Engelmann spruce stands, broadcast burning can be used to prepare seedbeds for natural regeneration. Fires must burn hot enough to remove most of the duff layer, but not so hot as to leave deep ash layers, such as beneath slash piles or windrows. If slash piles or windrows are decided upon due to the large amounts of slash remaining after clear-cutting, piles should be small and spread out. Broadcast burning is not recommended following partial cuts, as residual Engelmann spruce will be injured or killed.

Wind throw is a common cause of mortality in Engelmann spruce (Alexander and Shepperd 1990). Windthrow is highest at sites with poor drainage or shallow and rocky soils, and at exposed slope positions. The spruce beetle (*Dendroctonus rufipennis*) and the western spruce budworm (*Choristoneura occidentalis*) are the most prolific of Engelmann spruce insect pests in the northern and central Rocky Mountains. Spruce beetle larvae and adults feed on the phloem layer (Hagle and others 2003). Trees are often completely girdled and killed. Trees attacked by spruce beetle are inoculated with blue stain fungi, and individuals not killed directly by the beetle later succumb to the fungi. Western spruce budworm larvae feed on new foliage throughout the spring and also mine buds, old needles, cones, and seeds. Defoliations can be severe and are typically followed by branch dieback, top kill, and tree mortality. Wood borers, including longhorned beetles (Family: Cerambycidae) and metallic wood borers (Family: Buprestidae), may also attack Engelmann spruce. Longhorned beetles and metallic wood borers rarely kill their hosts, they usually only attack weakened and recently downed trees.

Wood rotting fungi are the most common disease agents of Engelmann spruce (Alexander and Sheppard 1990). Wood rotting fungi result in reduced marketable volume and predispose trees to wind throw. Common stem and root diseases include Annosus root disease (*Heterobasidion annosum*), Schweinitzii root and butt rot (*Phaeolus schweinitzii*), red belt fungus (*Fomitopsis pinicola*), and red ring rot (*Phellinus pini*) (Hagle and others 2003). Above timberline, where Engelmann spruce occurs in krummholtz stands, brown felt blight (*Neopeckia coulteri*) develops on needles that are buried in snow and keeps them moist for prolonged periods of time in the spring. The infected needles become matted together by a dark brown mat of mycelium and eventually are killed. Brown felt blight is rarely lethal.

Engelmann spruce is an unimportant browse species for wild and domestic ungulates (Uchytil 1991b). However, associated understory species provide important browse and forage for a variety of wildlife. Dense stands of Engelmann spruce provide important thermal and hiding cover for elk, mule deer, moose, black and grizzly bear, and bighorn sheep. The seeds are readily eaten by small mammals and birds, including red squirrels, chipmunks, mice, voles, chickadees, nuthatches, crossbills, and pine siskin. Large Engelmann spruce snags provide important feeding and nesting opportunities for a variety of cavity nesting birds. Engelmann spruce is recommended for the rehabilitation of cool, moist, high-elevation disturbed sites, especially mine spoils. Timber harvesting methods that reduce the susceptibility of residual Engelmann spruce to windthrow are recommended, including clear-cutting, shelterwood, and individual tree selection. If clear-cutting or shelterwood cuts are implemented, careful consideration should be given to locating wind-firm leave areas between cutting units (Alexander and Shepperd 1990).

Shrub Species

Rocky Mountain maple

Acer glabrum Torr.

Rocky Mountain maple is an upright, deciduous, tall shrub or small tree that ranges in height from 2 to 10 m (Francis 2004a). Rocky Mountain maple is rarely single-stemmed, most often featuring a clumped growth form with multi-stems originating from a common base. The bark is thin, smooth, grayish-brown and occasionally reddish.

Rocky Mountain maple occurs continuously from southeast Alaska through British Columbia and western Alberta (Thompson and others 1999). In southern British Columbia and Alberta, the distribution of Rocky Mountain maple follows two separate paths. One path follows the Coast and Cascade ranges in Washington and Oregon, and continues southeast through the Sierra-Nevada Mountains of California. The second follows the Rocky Mountains through northern, central, and southeastern Idaho; western and central Montana and Wyoming; and south into Utah, Colorado, and northern New Mexico. Outliers from this general trend, include the Wallowa and Blue Mountains of northeastern Oregon, the Bighorn Mountains of north-central Wyoming, western South Dakota and Nebraska, and scattered mountain ranges across Nevada, Arizona, southern New Mexico, and northern Mexico (Francis 2004a). Six varieties of Rocky Mountain maple, corresponding to six distinct geographic regions, are currently recognized by taxonomists: var. *diffusum* from the Pacific southwest, var. *douglasii* from the Pacific Northwest, var. *greenei* from California, var. *glabrum* from the inland Rocky Mountains, var. *neomexicanum* from the inland southwest, and var. *torreyi* from Oregon, California, and Nevada.

Rocky Mountain maple occurs in riparian areas, along steep canyon walls, and on upland mountain slopes (Anderson 2001a). It is often restricted to riparian areas, topographic depressions, or north-facing slopes within the most arid range of its geographic distribution. In general, the elevation range of Rocky Mountain maple increases with decreasing latitude. In southeast Alaska, British Columbia, and Alberta, Rocky Mountain maple occurs between 350 and 1,450 m. Across the Pacific coast and into northeastern Oregon, northern Idaho, and northwestern Montana, the species occurs between 457 and 2,743 m. In the Rocky Mountains of central Idaho, southwestern Montana, and northwestern Wyoming, Rocky Mountain maple occurs between 1,160 and 2,530 m (Steele and others 1981,and others 1983). On the east slope of the Wind River Range in Wyoming, Rocky Mountain maple occurs between roughly 1,800 and 2,900 m (Massatti 2007). In the southern portion of its range, including Colorado, Utah, Arizona, and New Mexico, the species is generally restricted to north-facing upland slopes and riparian areas between 1,524 and 3,871 m.

Rocky Mountain maple grows on a variety of soil textures, including silty-clay loam, silt-loam, sandy-loam, loamy-sand, and sand. It also occurs on a variety of substrate types, including sandstone, limestone, basalt, gneiss, rhyolite, granite, and mixed alluvium (Anderson 2001a). Rocky Mountain maple is often found growing in extremely bouldery soils (Wells 2006), ccupies soils ranging from well drained to somewhat poorly drained, and is tolerant of periodic flooding and temporary saturation (Anderson 2001a). The species is weakly to moderately drought tolerant, responding to changes in moisture level by adjusting total leaf area through stomatal control and shifting leaf water potential.

Rocky mountain maple features both monoecious and dioecious trees, the flowers of which are small, greenish, and borne in loose, terminal, corymbose cymes (Francis 2004a). Flowers first develop in early spring, and fruits mature by late summer or early autumn. The fruits are double-samaras, which feature wings to aid in dispersal by wind, and require approximately 6 months of chilling to germinate (Anderson 2001a). The species reproduces vegetatively by resprouting from the root crown following stem damage or top kill.

Rocky Mountain maple is considered shade intolerant to somewhat shade tolerant and is found in early seral to late seral and climax forested vegetation (Anderson 2001a). However, its presence has been found to decrease in later seral stages. This species is an important colonizer of disturbed sites, including avalanche paths, burned slopes, floodplains, and landslide deposits, and experiences its most rapid growth in open- to partially close-canopied stands within the first 20 years following a disturbance event. Rocky Mountain maple, a fire-dependent species, may decline in abundance with fire exclusion. This species readily colonizes burned areas by wind-dispersed seeds and root sprouting. Rocky Mountain maple is top-killed by even low intensity fires due to its thin bark. However, fire actually stimulates resprouting, and even high intensity burns are rarely fatal.

Managers considering the use of prescribed fire to increase the abundance of Rocky Mountain maple should consider using low to moderate intensity burns, as high intensity burns can result in less successful regeneration and an overall loss of vigor. Silvicultural treatments, including thinning, clear-cutting, and shelterwood cuts, may also lead to an increase in the overall density of Rocky Mountain maple. However, severe damage to the root crown due to mechanical disturbance will decrease the abundance of Rocky Mountain maple following silvicultural treatments. Lastly, the abundance of Rocky Mountain maple stems may be increased by removing old stems above the root crown.

Rocky Mountain maple is an important browse species for domestic and wild ungulates, and in early seral stands, provides hiding and thermal cover for a variety of wildlife, including mule deer, elk, birds, and small mammals (Anderson 2001a). Heavy browsing by ungulates in the early stages of development may arrest the development of Rocky Mountain maple, and result in a stunted growth form. In areas where browse intensity is low to moderate, Rocky Mountain maple will eventually grow above the reach of browsing ungulates. Rocky Mountain maple is commonly used in rehabilitation of disturbed sites following highway construction and for revegetation projects in riparian areas across the western United States.

Red-osier dogwood

Cornus sericea (L.)

Red-osier dogwood is a widespread species that occurs across North America from Alaska and the Yukon Territory in the northwest to California, Arizona, and northern Mexico in the southwest (Crane 1989). In the northeast, red-osier dogwood occurs across New England and into New Brunswick, Labrador, and Newfoundland. Across the Midwest and central eastern United States, red-osier dogwood occurs most prominently in previously glaciated areas, and in northern Kentucky, Virginia, and West Virginia at locally favorable sites.

Red-osier dogwood has high environmental plasticity and is tolerant of a wide array of soil and climatic conditions (Pijut 2004). It is most often found in riparian zones and wetlands in nutrient rich, medium- to coarse-textured, moist to wet soils (Crane, 1989). Permanent soil saturation within the upper rooting zone is detrimental to this species. Red-osier dogwood is found close to sea level near the Pacific Coast and in deep canyon (400–1,200 m), mid-montane (1,200–1,800 m), and lower subalpine (1,800–2,700 m) riparian zones and wetlands throughout the Rocky Mountain region of eastern Oregon and Washington, Montana, Idaho, Wyoming, and Nevada (Youngblood and others 1985; Hansen and others 1995; Manning and Padgett 1995; Crowe and Clausnitzer 1997; Kovalchik and Clausnitzer 2004; Wells 2006). On the east slope of the Wind River Range in Wyoming, red-osier dogwood occurs between roughly 1,800 and 2,900 m (Massatti 2007). It occurs between 1,372 and 3,048 m in Colorado, 1,463 and 2,896 m in Utah, and 1,524 and 2,743 m in Arizona (Crane 1989). Red-osier dogwood adapts to extremely cold winter temperatures by partial dehydration of stems in response to shortened day length.

Red-osier dogwood is a fast-growing, medium to tall (1–6 m), deciduous shrub with bright red stems and twigs (Crane 1989). Multiple stems sprout from a single root crown, often producing dense thickets along stream banks. The white- to cream-colored flowers are insect pollinated, and occur in cymes at the end of branches (Pijut 2004). The fruits are globose drupes that have a hard white- to gray-colored seed coat and dormant embryos, and are primarily dispersed by mammals and birds. Seeds may be stored in the seedbank for extended periods of time, and germination is enhanced by cold stratification and scarification by fire or in the digestive tract of mammals or birds (Crane 1989). Red-osier dogwood also reproduces asexually by stolons, layering, adventitious roots, and stem suckering. Asexual reproduction is stimulated by mechanical damage to the plants, including fire, browsing, and damage due to spring flood events. Red-osier dogwood is an early to mid-seral species that has low shade tolerance, and requires moderate to full sunlight.

This species is semi fire tolerant and is able to sprout from surviving roots, stolons, and the base of aerial stems following low to moderate severity burns (Crane 1989). Severe burns causing intense heating of upper soil horizons may lead to root mortality. Fire stimulates germination of seeds stored in the seed bank. In general, red-osier dogwood responds favorably to low to moderate severity burns, and due to its vigorous growth, fire stimulated buds and seeds, is often the first species to regenerate following fire.

Red-osier dogwood is an important browse and cover species for moose, white-tailed and mule deer, elk, mountain goats, and snowshoe hares (Crane 1989). Livestock eat this species, but it is moderately unpalatable and not strongly preferred. The fruits, which remain on the plant well after the fruits of other plants have disappeared, are a preferred food item of many songbirds, grouse, black and grizzly bears, ducks, crows, and mice. Young stems and bark of red-osier dogwood are a preferred food item of deer mice and voles, while adult stems are used by beavers to build dams and lodges. Red-osier dogwood is extremely important in streambank stabilization owing to its strong roots and dense stems. This plant is strongly recommended for revegetating disturbed riparian zones and wetlands because it is easy to establish and grows rapidly, and its dense, interweaving roots help with soil stabilization. Red-osier dogwood may increase with light to moderate browsing pressure; however, prolonged, intense pressure by browsing ungulates may eliminate red-osier dogwood.

Common juniper

Juniperus communis L. var. depressa Pursh

Common juniper is a widespread conifer species and includes five subspecies or varieties occurring on all continents throughout the northern hemisphere (Pojar and Mackinnon 1994). The variety *Juniperus communis* var. *depressa* is present in the Rocky Mountains and is a low shrub, typically 3 m tall or less. The species is intolerant of shade and prefers open canopy forested communities with high amounts of solar radiation (Ward 1982a). Common juniper is a hardy shrub tolerant of a wide range of environmental conditions (Ladyman 2004a). Despite its environmental plasticity and the availability of potential habitat types, the species' distribution is often patchy, and the spatial distribution of common juniper is often difficult to explain (Diotte and Bergeron 1989).

This plant is a dioecious shrub with female cones that resemble berries in appearance, develop in April through May, and ripen in August through September every two–three years (Tirmenstein, 1999b; Ladyman, 2004a). The seeds are dispersed primarily by birds and require a lengthy maturation and germination period, including 3 months of warm weather followed by 7 months of cold conditions (Livingston 1972). Also, reproductive success, including fecundity (sterility in 40–60% of old individuals) and viability of seeds (non-viability in 94.8% of seed producing old plants) decreases with increasing age of common juniper (Ward 1982b). Poor seed dispersal combined with low germination rates and decreased reproductive success of older individuals is considered an important factor influencing the often patchy distribution of common juniper relative to the distribution of potential habitat sites (Ladyman 2004a).

The mosaic of burned and unburned areas created by forest fire is another important factor influencing the patchy distribution of common juniper relative to the distribution of potential habitat sites. Common juniper is intolerant of forest fire and is generally killed or seriously damaged by moderate to severe burns and rarely re-sprouts from rootstock following fire (Tirmenstein 1999b). Following low intensity or spreading, patchy burns, individuals surviving in an area provide seed for regeneration. However, the success of regeneration from seed of surviving individuals depends strongly on the age of those individuals that survived. In the case of high intensity burns, where this species is completely obliterated across broad areas, birds and small mammals carry seeds from off-site, providing a pathway for re-establishment. However, re-colonization from off-site is often extremely slow due to poor seed dispersal and low germination rates. Lastly, Diotte and Bergeron (1989) concluded that the restricted distribution of this species in the boreal forests of Quebec, despite an abundance of favorable habitats, was related to the imbalance between the slow colonization period and the elimination by fire.

Common juniper is a valuable species for long-term rehabilitation projects and is useful in mitigating soil erosion (Tirmenstein 1999b). When planting this species for rehabilitation, the best results may be obtained by planting bare rootstock in the spring of the year. Mule deer sometimes browse common juniper in late winter and early spring. The cones of this species are consumed by songbirds, including American robins and chickadees. Domestic livestock rarely feed on common juniper, which may be poisonous to domestic goats. The seed cones of common juniper are used to flavor gin, and the word for this alcoholic beverage was derived from the Old French and Dutch words "genevre" and "genever," respectively, which ultimately find their roots in the Latin word "juniperus."

Oregon grape

Mahonia repens (Lindl.) G. Don

Oregon grape is an upright, recumbent, evergreen shrub with solitary stems arising from fibrous rhizomes and standing 12 to 40 cm in height (Francis 2004b). The alternate, pinnately compound leaves feature three to seven leathery, spiny-toothed leaflets. The yellow flowers occur clustered at the end of terminal racemes. The fruits are oblong to round, glaucous, blue berries, and appear much like a cluster of grapes.

Oregon grape occurs from east-central British Columbia and southern Alberta; south, central, and northwestern New Mexico; and the northeastern half of Arizona (Whittemore 1997). West of the Continental Divide, the geographic distribution of this species extends to the eastern slope of the Cascade Range in Washington and Oregon and into extreme northeastern California. In Nevada, the this species occurs primarily in the northeastern half of the state, with a small population in the extreme northwestern corner. East of the Continental Divide, the geographic range extends to southwestern North Dakota, extreme western South Dakota and Nebraska, and the front range of Colorado. Outliers to this general distribution include locations in north central Minnesota, northeastern South Dakota, and extreme western Texas.

Oregon grape grows at elevations ranging from near sea level on the Pacific coast to nearly 3,350 m in Colorado (Johnston and others 2001; Uley 2006). In the central Rocky Mountains, this species typically occurs from 1,370 to 2,700 m in Douglas-fir forests to 2,400 to 2,900 m in subalpine fir forests (Steele and others 1981,and others 1983). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 2,200 and 2,900 m (Massatti 2007). This species occurs on a variety of slope aspects across its geographic range. Generally, within the lower elevation range, it is restricted to cool, moist northerly aspects (Steele and others 1983; Youngblood and Mauk 1985). Within the upper elevation range, it shifts onto south- and west-facing slopes (Svalberg and others 1997; Youngblood and Mauk 1985). At middle elevations, it may occur across all aspects.

Oregon grape prefers medium-textured, well-drained sandy loam soils formed from a variety of parent materials, including sandstone, limestone, dolomite, andesite, conglomerate, basalt, granite, gneiss, schist, and glacial till (Steele and others 1983; Svalberg and others 1997; Uley 2006). This species may also occur on fine-textured soils derived from shale and siltstone (Svalberg 1997), and on coarse, rocky soils on exposed slope positions (Uley 2006) and tolerates strongly acid to mildly alkaline soils (pH 4.6–7.6). Oregon grape is intolerant of prolonged soil saturation; however, this species commonly occurs on stream terraces in well-drained soils (Wells 2006) and in moist quaking aspen communities in topographic depressions (Mueggler 1988).

Oregon grape is a monoecious, seed banking species that is pollinated by bees and butterflies (Ulev 2006). Good seed crops are produced nearly every year from cross-pollinated plants. Self-pollination may occur but often results in sterile fruits. The seeds require one to three months of cold-stratification for germination to occur. Seedling establishment and growth is rapid following a disturbance but generally decreases as stand age and overstory cover increases. This species regenerates asexually by rhizomes and layering.

Oregon grape is tolerant of full sun and partial to deep shade (Uley 2006). It is present at all seral stages and is often considered a climax shrub species largely due to the ability of this species to tolerate the intense shade experienced in the understory of climax conifer stands. The ability of this species to re-sprout from underground rhizomes, makes it well adapted to forest fire. Low to moderate severity burns actually stimulate growth, often resulting in increased vigor in the years immediately following a fire. Also, forest fires may result in the germination of seeds stored in the seed bank. However, severe burns that remove the duff layer and heat the upper mineral soil may kill the underground rhizomes, resulting in mortality.

Oregon grape is slightly poisonous and unpalatable to domestic livestock (Uley 2006). However, it is an important browse species for wildlife, including mule deer, elk, grouse, black and grizzly bears, snowshoe hare, and small mammals. The ability of this species to spread via rhizomes and its hardy nature make it important in protecting slopes against erosion and for use in restoration projects.

Gooseberry Currant

Ribes montigenum McClatchie

Gooseberry currant occurs continuously from British Columbia and Alberta; southeast through central Montana, Idaho, and northwestern and central Wyoming; and south through Utah, Colorado, Arizona, and New Mexico (Marshall 1995). To the west, this species occurs along the Cascade Range of Washington and Oregon, south to the Sierra-Nevada Mountains of California, and in scattered mountain ranges in Nevada. Gooseberry currant grows across a variety of sites ranging from the middle subalpine zone to timberline and occasionally in alpine plant communities. It is tolerant of extremely rocky soils such as talus or scree slopes and boulder fields as well as somewhat poorly drained soils and temporary soil saturation. This species occurs at elevations between 2,000 and 2,600 m in northeastern Oregon (Johnson 2004), between 2,273 and 3,485 m in Wyoming and Colorado, between 2,100 and 4,800 m in California, and between 2,135 and 3,660 m in Utah (Marshall 1995). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 2,600 and 3,350 m (Massatti 2007).

Gooseberry currant is a native, deciduous, low to medium tall shrub ranging in height between 0.2 and 1 meter (Marshall 1995). The glandular-pubescent, orbicular, five-lobed leaves occur alternately along spiny branches. The flowers occur in drooping three- to eight-flowered racemes,and the fruits are globose-subglobose, reddish, glandular-hairy berries (Hitchcock and Cronquist 1973). This species reproduces by seed and by rooting of adventitious roots. Fruiting usually begins after three years, and scarification is required to enhance germination (Marshall, 1995). Seeds are primarily animal and bird dispersed and may remain viable in the seed bank for many years.

Gooseberry currant is somewhat shade tolerant and is often found growing in moderately dense to dense conifer stands (Marshall 1995). Information on the fire ecology of gooseberry currant is limited. However, it is probable that fire enhances regeneration by scarification of seeds stored in the seed bank and that itmay resprout from the root crown following fire with varying success. Gooseberry currant is sensitive to fire and is probably killed by low to moderate severity burns. Its berries are an important food source for songbirds, chipmunks, and ground squirrels. However, this species has low palatability for domestic and wild ungulates. Gooseberry currant is one of a number of currant (*Ribes* spp.) species that provides an alternate host for white pine blister rust (*Cronartium ribicola*), a lethal fungi that infects five-needle pines.

Russet buffaloberry

Shepherdia canadensis (L.) Nutt.

Russet buffaloberry is a widespread species, occurring in western North America from Alaska and adjacent Yukon Territory, south along the Rocky Mountains to Arizona and New Mexico (Walkup 1991). In central and eastern North America, it occurs from the Black Hills in South Dakota; east across Minnesota, Wisconsin, Michigan, northern Pennsylvania and Ohio, western New York, and Maine; and into Nova Scotia and Newfoundland. The northerly limits of this species are located within the Arctic Circle across Alaska and northern Canada.

Russet buffaloberry is found growing in soils derived from a number of parent materials, including granite, sandstone, basalt, limestone, dolomite, and shale (Steele and others 1983; Johnston and others 2001). However, regardless of parent material, soils where this species is found are typically coarse-textured and rocky (Walkup 1991). Russet buffaloberry has relatively high environmental plasticity and can be found in extremely dry, rocky uplands and in mesic valley bottoms, on glacial moraines, and on alluvial terraces. It occurs at elevations between 1,500 and 1,600 m in Alberta, 1,829 and 2,439 m in northeastern Oregon (Johnson 2004), 1,219 and 2,378 m in Montana (Pfister and others 1977), 2,012 and 2,499 m in Idaho (Walkup 1991), 2,255 and 2,652 m in eastern Idaho and western Wyoming (Steele and others 1983), and between 2,759 and 3,231 m in Colorado (Johnston and others 2001). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 2,100 and 3,200 m (Massatti 2007). Russet buffaloberry is moderately shade tolerant and is one of the first species to inhabit a site following disturbance (Walkup 1991).

Russet buffaloberry is a moderately tall to tall (0.9–3.9 m), native, deciduous, nitrogen-fixing shrub that is usually dioecious and occasionally monoecious (Walkup 1991). Regeneration is by seed or vegetatively by sprouting from the root crown or dormant buds on the taproot. It reaches sexual maturation at four to six years. Flowering occurs from mid-May to mid-June, and the fruits (drupe-like, ovoid achenes enclosed in a fleshy perianth) ripen and turn yellowish-red to bright red between July and early August. Germination, which can be highly erratic, is enhanced by cold stratification for a minimum of 60 days and scarification by fire, or in the gastrointestinal tract of mammals and birds.

Russet buffaloberry is moderately fire resistant and can sprout from surviving root crowns and dormant buds on the taproot (Walkup 1991). Low to moderate severity ground fires are critical to maintaining high density and vigor and increasing berry production in old-growth conifer stands, while severe fires can sometimes be fatal. It provides hiding and thermal cover for wildlife and has one of the highest protein levels of any browse species. However, it is of low palatability to domestic and wild ungulates and is only utilized in the absence of other more palatable browse species. The fruits are widely utilized by black bears, grizzly bears, and grouse. This species is highly recommended for revegetation of disturbed sites due to its nitrogen fixing capabilities and its importance as food and cover for wildlife.

Utah snowberry

Symphoricarpos oreophilus var. utahensis Gray (Rydb.) A. Nels.

Utah snowberry is a native, deciduous shrub that occurs east of the Coast Range in British Columbia, east of the Cascade Ranges in Washington and Oregon, and into northeastern California, Nevada, and Arizona (USDA, NRCS 2007b). To the east, it occurs in Idaho, Wyoming, Utah, Colorado, and scattered mountain ranges in New Mexico and Montana. Mountain snowberry (*Symphoricarpos oreophilus* var. *oreophilus*) is closely related to Utah snowberry and is limited to northern Mexico and the southwestern United States, including northern and eastern Nevada, southern Utah, northeastern Arizona, western New Mexico, and far western Texas.

Utah snowberry occurs most prolifically on warm, dry sites, in the lower to mid-forested zone, on moderately steep (30–45%) to steep (45–70%), south- or west-facing slopes, but also on gentle gradients and on northerly aspects. In northeastern Oregon, it occurs at elevations between 1,707 and 2,378 m (Johnson 2004). In the northern and central Rocky Mountains of Montana, Wyoming, and Idaho, it occurs at elevations between 1,738 and 2,134, 1,829 and 2,789, and 1,370 and 2,440 m, respectively (Steele and others 1981, 1983; Aleksoff 1999). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 2,200 and 2,900 m (Massatti 2007). In the southern Rocky Mountains of Utah and Colorado, it occurs at elevations between 1,220 and 3,200 m (Aleksoff 1999). This species occurs on a variety of substrates, including limestone, calcareous shale, sandstone, quartzite, basalt, andesite, rhyolite, quartz monzonite, and granodiorite (Steele and others 1981, 1983). Soils tend to be gravelly to extremely gravelly, and textures are generally medium to coarse, including loamy sand, sandy loam, loam, and silt loam.

Utah snowberry is a low (0.3–0.6 m) to medium (0.6–1.2 m) erect and sometimes trailing shrub that is weakly rhizomatous (Aleksoff 1999). The pinkish to white flowers, which begin to bloom from mid-June to early July, occur in groups of two to four at leaf axils and terminally on branches (Hitchcock and Cronquist 1973). The fruits, which are white, drupe-like berries, ripen in mid-August and are mammal and bird dispersed (Aleksoff 1999). Cold-stratification is required for full embryo development, and seeds are not stored in the seed bank for extended periods of time. It also regenerates vegetatively by sprouting from the root crown. This species is an early to mid-seral species that is intolerant of shade. However, it will persist in old-growth forests if trees are widely spaced, allowing appreciable amounts of sunlight to reach the understory.

Utah snowberry will resprout from basal buds on the root crown following low to moderate severity burns and often survive severe fires (Aleksoff 1999). It is not especially nutritious or palatable but remains an important browse species for domestic and wild ungulates, including cattle, domestic sheep, horses, pronghorn, elk, and mule deer. Low to moderate levels of browsing will stimulate Utah snowberry to sprout profusely, while heavy browsing can significantly reduce plant density. Grouse and magpies eat the fruits, and dense thickets provide thermal and hiding cover for songbirds, grouse, and a variety of small mammals. It is important for providing soil stability and reducing the effects of erosion, and it is recommended for rehabilitation of disturbed sites due to road building, severe fire, or logging.

Grouse whortleberry

Vaccinium scoparium Leib. ex Coville

Grouse whortleberry occurs from eastern British Columbia and western Alberta, south through Washington and Oregon, mostly east of the Cascade Range, California, and in scattered mountain ranges in Nevada and Arizona (Johnson 2001b). To the east, it occurs in western Montana and northern and central Idaho, south through northwestern and central Wyoming, and into Colorado, Utah, and northern New Mexico. The eastern-most population occurs separate from the central distribution in the Black Hills of South Dakota.

Grouse whortleberry is a common low-shrub species in montane, subalpine, and timberline forests across its geographic distribution. It often extends above timberline where it grows in krummholz vegetation. The elevation range of this species, as with many montane species, increases with decreasing latitude. In northeastern Oregon and Montana, it occurs in montane and subalpine forests between 1,707 and 2,652 m, and 1,829 and 2,469 m, respectively (Steele and others 1981; Johnson and Simon 1987; Johnson 2004). In Wyoming and eastern Idaho, conifer forests with a significant grouse whortleberry component occur between 1981 to 3,293 m, and in alpine vegetation above 3,293 m (Steele and others 1983; Svalberg and others 1997). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 2,500 and 3,500 m (Massatti 2007). In the Rocky Mountains of Colorado, it occurs between 2,591 and 3,810 m (Johnston et al 2001). At the lowest elevations, it is typically limited to north-facing slopes and/or cold air drainages.

Grouse whortleberry typically grows on well drained, dry to moist, rocky (35–75% coarse fragments) soils with a thin (1–4 cm) to moderately thick (5–9 cm) litter layer. Soil textures of the first mineral horizon are often loamy, including silt loams, loams, sandy loams, fine sandy loams, or very fine sandy loams (Svalberg and others 1997). This species grows on a wide variety of substrates, including calcareous rock types. However, like most *Vaccinium* species, grouse whortleberry requires acidic soils (pH 4.3–5.2) and is most commonly found on igneous, metamorphic, and non-calcareous sedimentary geologies, including gneiss, schist, granite, granodiorite, quartz monzonite, argillite, sandstone, quartzite, breccia, volcanic ash, basalt, and granitic glacial till (Steele and others 1981, 1983; Svalberg and others 1997; Johnston and others 2001; Johnson 2004).

Grouse whortleberry is a rhizomatous, deciduous, low-growing shrub, reaching 10 to 51 cm in height (Johnson 2001b). It has the ability to reproduce vegetatively via rhizomes, which usually occur in the litter layer, or at the interface between the mineral soil and litter. Flowering begins in late spring or early summer, and the small, inconspicuous, urn-shaped flowers develop into bright red berries by early fall. Upon ripening, the seeds require no dormancy period and are dispersed primarily by birds and mammals, including black and grizzly bears.

Grouse whortleberry is moderately resistant to fire, resprouts from rhizomes following fire, and is adapted to low to moderate severity burns that do not kill the shallow rhizomes (Johnson 2001b). Severe burns that destroy the litter layer and kill the shallow rhizomes can extirpate it from an area. Management activities that severely destroy the litter layer and uproot it, including site preparation treatments, mechanical logging, and road building, may also have deleterious effects on the regeneration success of this species. It is an important, energy-rich browse species for wild ungulates, including mule deer, elk, and moose in Montana, Wyoming, and Utah (Johnson, 2001b). The berries are a valuable food source for black and grizzly bears, chipmunks, red squirrels, fox, grouse, and a variety of songbirds. This species has low to moderate value for revegetation projects.

Herbaceous Species

Heartleaf arnica

Arnica cordifolia Hook.

Heartleaf arnica occurs across western North America from Yukon and Northwest Territories in the north to California, Arizona, and New Mexico in the south (Wolf 2006). It occurs to the east as far as Ontario and South Dakota. A disjunct population occurs in northern Michigan (Reed 1993).

Heartleaf arnica is a common woodland species, occurring in deep canyon (700–1,270 m), montane (1,050–1,829 m), subalpine (1,829–3,200 m), and upper timberline forests (3,000–3,500 m). On the east slope of the Wind River Range in Wyoming it occurs between roughly 1,800 and 3,500 m (Massatti 2007). This species occurs in uplands and on terraces in riparian areas on cool, dry to moist sites, in soils derived from all major rock types, including igneous, sedimentary, and metamorphic (Steele and others 1981, 1983; Johnson and Simon 1987; Svalberg and others 1997; Johnston and others 2001; Johnson 2004; Wells 2006). Soils where this species occurs are highly variable but are typically well drained to moderately well drained and feature an organic surface layer over mineral soil.

Heartleaf arnica is a native, perennial herb that stands 10 to 60 cm tall and features erect stems arising individually from long creeping rhizomes (Reed 1993). This species reproduces sexually by wind-dispersed seeds and asexually from rhizomes. It may be found in early to late seral stands, largely due to its tolerance of both sun and shade. Often times, it is one of the only herbaceous species in closed-canopied, late seral conifer stands. The abundance of this species generally increases in the initial years following disturbance, after which it begins to slowly decline in abundance in mid-seral stands. In later seral stages, this species usually begins to show an increase in abundance possibly due to vegetative reproduction.

The above ground portions of heartleaf arnica are typically killed by fire (Reed 1993). However, the rhizomes generally survive low to moderate intensity burns that consume the litter layer. Following fire, it rapidly regenerates from rhizomes and inundates burned areas with heavy seed crops. This species is eaten by mule deer and elk and occasionally by domestic sheep and cattle and is susceptible to trampling by humans and livestock.

Ross' sedge

Carex rossii Boott

Ross' sedge is a widespread western cordilleran species that occurs from Alaska, Yukon, and Northwest Territories south through British Columbia, Alberta, and Saskatchewan, and in all western states to Arizona and New Mexico (Ball and Reznicek 2002). East of the Rocky Mountains, it occurs in Manitoba, Ontario, South Dakota, Nebraska, Wisconsin, and Michigan.

Ross' sedge is a common woodland species, occurring in deep canyon (910–1,280 m), montane (1,280–1,820 m), subalpine (1820–3200 m), and upper timberline forests (3,000–3,640 m) (Cope 1992). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 1,800 and 3,400 m (Massatti 2007). It occurs in uplands and on terraces in riparian areas on cool, dry to moist sites, in soils derived from all major rock types, including igneous, sedimentary, and metamorphic (Steele et al 1983; Johnson and Simon 1987; Svalberg and others 1997; Johnston and others 2001; Johnson 2004; Wells 2006). Soils where this species occurs are highly variable but are typically well drained to moderately well drained and feature an organic surface layer over sandy-loam to loam mineral soil.

Ross' sedge is a native, densely cespitose, rhizomatous sedge with 7 to 30 cm tall flowering stems (Ball and Reznicek 2002). It reproduces sexually by seeds, which germinate best following heat treatment, and asexually from rhizomes (Cope 1992). Seeds may be stored in the soil for extended time periods before germination. This species is partially shade tolerant and increases following disturbance. Although Ross' sedge gradually decreases in abundance through time, a few individuals commonly persist into climax stands. On especially dry and unproductive sites, it is often one of the only understory species in older lodgepole pine, subalpine fir, and whitebark pine stands.

Ross' sedge resists low to moderate severity fires that do not completely consume the litter layer (Cope 1992). It reproduces prolifically following fire from buried rhizomes and seeds stored in the soil. This species is grazed by both wild and domestic ungulates. Nutritional value, including protein, phosphorus, calcium, and fat content, tends to increase throughout the growing season. It is an important erosion control species due to its extensive rhizomes and ability to resprout rapidly following disturbance.

Tufted hairgrass

Deschampsia cespitosa (L.) P. Beauv.

Tufted hairgrass occurs circumglobally in arctic and temperate regions (Walsh 1995). In North America, it occurs in all Canadian Provinces and western States, including Alaska (USDA, NRCS 2007b). The distribution of this species extends eastward across the Dakotas and Minnesota, through the mid-Atlantic States, and into New England. On the Shoshone National Forest in Wyoming, it occurs at elevations between roughly 2,300 and 3,800 m (Massatti 2007). This species is common in subalpine meadows, fens, floodplains, bogs, seeps, and late snowbank environments in the alpine zone. The persistence of soil moisture within the rooting zone throughout the growing season is a common feature of sites inhabited by this species. It occurs on a variety of soil textures, including sedge peat, sandy-loam, sandy clay loam, silty clay loam, silt-loam, loam, and loamy-clay (Kovalchick 1987; Hansen and others 1995; Walsh 1995; Wells 2006).

Tufted hairgrass is a densely cespitose, native, cool-season, perennial bunchgrass with slender, hollow culms that stand 20–120 cm in height (Walsh 1995). The inflorescence is typically a loose, open panicle 10 to 30 cm long with whorled branches. It reproduces primarily by seed but will also sprout from the rootcrown following disturbance by fire and grazing. The seeds may remain viable in the seedbank for a number of years, and it will resprout from the rootcrown following low to moderately severe fires (Walsh 1995). Regeneration is primarily from seed following severe fires that destroy the above ground portions of the plant. This species provides excellent forage for all types of livestock and is an important food item for elk, mule deer, waterfowl, and small mammals. It is a decreaser and with excessive grazing will gradually give way to other species, especially *Poa pratensis*. However, this species is tolerant of moderate amounts of grazing, especially when (1) land managers choose a grazing practice that allows for significant seed production before grazing takes place, and (2) periodic graze free years are incorporated into the grazing schedule to allow time for recovery. Also, in order to avoid excessive sod damage and soil compaction, grazing should be postponed until later in the growing season when the soils have dried up (Kovalchik 1987).

Spike fescue

Leucopoa kingii (S. Wats.) W.A. Weber

Spike fescue is a native, perennial bunchgrass that occurs in the north from northeastern Oregon, to west-central and southeastern Idaho, to southwestern and central Montana (USDA, NRCS 2007b). To the south, it occurs in eastern California, Nevada, Utah, Wyoming, and northwestern Colorado. The eastern extent of the range of this species includes South Dakota, western Nebraska, and Kansas.

Spike fescue occurs across a range of habitats, including plains grasslands, sagebrush steppe, subalpine forests, and alpine meadows (Anderson 2005). In forested communities, trees are widely spaced and the stands take on a savannah-like appearance. It is often found on warm, xeric, and droughty sites. This species occurs between 2,400 and 3,080 m in Idaho and between 1,341 and 2,530 m in Montana (Pfister and others 1977; Anderson 2005). In Colorado, Wyoming, and Utah, it occurs at 1,670–3,050 m, 1,830–3,400 m, and 1,370–3,660 m, respectively (Anderson 2005). On the east slope of the Wind River Range in Wyoming, it occurs between roughly 1800 and 3700 m (Massatti 2007). This species grows on all major rock types, including sedimentary, igneous, and metamorphic, and in a variety of soil textures, from gravelly and stony to clay-loam and silt. However, moderately deep, well-drained, loamy, slightly alkaline soils (pH ~7.4) are most preferred.

Spike fescue is a cool season, rhizomatous bunchgrass that forms dense tufts with 30 to 90 cm tall flowering stems (Anderson 2005). The rhizomes often grow in a circular pattern, forming large, ring-like tufts upwards of 2 m in diameter. It is most often a dioecious species that features intersexual habitat assortment. It reproduces vegetatively from creeping rhizomes and sexually from wind dispersed seed. Spike fescue is intolerant of deep shade and requires partial to full sun, and is tolerant of periodic, low- to moderate-intensity fires that typically kill the above ground portions of the plant (Anderson 2005). It is considered an increaser following fire, as the underground rhizomes vigorously resprout following low- to moderate-intensity fires. High intensity fires may kill underground rhizomes, in which case, post-fire regeneration is from off-site seed sources.

Spike fescue is a highly nutritious and palatable grass for domestic and wild ungulates, especially in the spring and early summer (Anderson 2005). The dense tufts of of this species are tolerant of moderate trampling and grazing pressure. However, spike fescue will decrease under constant heavy grazing pressure and continual trampling.

Appendix 7: Environmental Characteristics for Minor Ecological Types

Abbreviations: stat = statistic (average, minimum, maximum); elev = elevation (m); slope = slope gradient (%), prec = average annual precipitation (mm); dd = degree days; ffd = frost free days; swb = site water balance (mm); temp = average annual temperature (°C); pet = potential evapotranspiration (mm); sumrad = summer radiation (Kj), frag = coarse fragments in the particle size control section (%), clay = clay in particle size control section (%), awc = available water capacity of soil (mm); pH = average weighted pH; aspect = cardinal direction of slope.

Ecological type	n	stat	elev	slope	prec	dd	ffd	swb	temp	pet	sumrad	frag	clay	awc	pH	aspect
ABLA/RIMO2, Cranbay	1	avg.	3009	17	703	11370	17.2	-102	-0.3	390	17370	28	21	64	4.9	NNW
ABLA/VASC, Swapps	2	avg.	3073	25	756	11070	17.5	-144	-0.5	461	20390	31	23	79	4.7	ENE, SSW
		min.	3044	23	743	10470	16.7	-156	-0.8	456	19860	21	21	64	4.6	
		max	3102	27	769	11660	17.4	-133	-0.2	465	20920	41	24	93	4.8	
ARTRV2/FEID, Kiev	2	avg.	2636	21	627	16370	19.7	-261	1.8	660	20980	24	18	116	8.1	SSW
		min.	2570	20	607	15750	19.3	-294	1.5	627	20960	23	14	105	7.9	
		max	2701	22	647	16990	20.0	-228	2.0	693	21010	25	22	128	8.2	
ARTRV2/FEID, Corbly 351L	1	avg.	2503	19	577	17320	20.2	-392	2.2	699	20930	79	4	17	5.6	SSW
ELSP3-POSE, Wabek	1	avg.	2270	53	477	20840	21.9	-460	3.6	786	20500	40	10	45	6.3	SSE
FEID, Ledgefork	1	avg.	2851	6	673	13310	18.2	-237	0.6	504	20020	71	10	21	5.3	NNW
JUPA, Oxyaquic soils	1	avg.	3240	6	823	9360	16.0	-166	-1.3	423	20587	99	4	22	4.8	
PIAL Series, Marosa	2	avg.	2772	31	669	14860	18.9	-178	1.1	543	19150	66	19	49	4.8	NE
		min.	2560	19	604	12670	17.8	NA	0.2	484	18660	65	18	42	NA	
		max	2983	43	733	17050	20.0	NA	2.1	601	19630	67	20	57	NA	
PIAL/VASC, Elting	1	avg.	3082	21	759	11580	17.2	-212	-0.2	504	20850	84	10	36	4.7	SE
PIAL/VASC, Sig	1	avg.	3182	10	795	10550	16.6	-146	-0.7	441	20310	30	16	48	4.9	W
PICOL/CARO5, Stecum	1	avg.	2734	3	657	14950	19.0	-305	1.2	585	20680	84	6	17	4.9	SE
PICOL/VASC, Telcher	2	avg.	2671	11	631	15940	19.5	-242	1.6	601	19950	18	17	78	5.3	ENE
		min.	2664	4	625	15870	NA	-273	NA	588	19840	3	11	59	NA	
		max	2678	17	637	16000	NA	-212	NA	614	20050	33	23	97	NA	
PIFL2/JUCOD, Como	1	avg.	2648	47	627	15930	19.4	-324	1.6	633	20950	61	5	44	6.3	SW
POTR5/COSE16-ALVIS Habitat Type	2	avg.	2542	31	585	17340	20.3	-270	2.2	644	19860	24	13	92	6.1	ESE, SSW
		min.	2531	19	578	16890	20.1	-327	2.0	594	18980	14	11	70	5.9	
		max	2552	42	592	17800	20.4	-213	2.3	693	20740	34	15	114	6.3	
PSMEG/ACGL, Yourame	1	avg.	2273	56	490	20565	21.8	-223	3.5	607	17826	50	26	137	7.0	N
PSMEG/SYORU, Typic Calciustepts	2	avg.	2440	61	567	18050	20.6	-158	2.5	486	16340	62	21	85	7.8	NNW, NW
		min.	2391	57	556	17740	20.4	-163	2.4	483	16250	59	17	78	7.6	
		max	2488	65	577	18360	20.7	-154	2.6	489	16430	65	24	91	8.0	
Oxyaquic soils, Elvick	2	avg.	2834	5	733	12520	17.7	-174	0.1	491	20260	43	12	71	5.2	ESE, NE
		min.	2691	2	638	9509	16.1	-262	-1.3	393	19940	36	8	66	4.9	
		max	3261	7	827	15530	19.2	-87	1.4	588	20570	49	16	76	5.5	
Salix/Carex–Kettle Lake, Fluvaquentic Cryaquepts ET	1	avg.	2671	2	642	15464	19.2	-256	1.4	613	20812	35	12	95	4.8	ESE

Appendix 8: Complete Constancy and Average Cover by Ecological Type of all Species Present

Constancy (CON) refers to the percentage of sample stands in which each species occurs (located on the left side of the cell; e.g., **CON** | COV).

Average Cover (COV) refers to the average percentage canopy cover of a species for the sample stands where it was recorded. For example, an ecological type may be composed of 12 sample stands, but a particular species may be present in only 5 of those stands. The average cover for that species is calculated as the average canopy cover in those five stands (located on the right side of the cell; e.g., CON | **COV**).

Life form (LF) codes: DO = dominant overstory tree, SD = subdominant overstory tree, U = understory tree, SEED = seedling, S = shrub F = forb, G = grass, GL = grasslike, FH = ferns and horsetails.

Appendix 8-1: Constancy and average cover of all species present in the following ecological types:

AB/AR-CAD Hierro = ABLA/ARCO9-CAD, Hierro Family ET
ABLA Elting = Warm ABLA Forests, Elting Family ET
AB/MA Frisco = ABLA/MARE11, Frisco Family ET
AB/RI Cranbay = ABLA/RIMO2, Cranbay Family ET
AB/RI Elting = ABLA/RIMO2, Elting Family ET
AB/VA Elting = ABLA/VASC, Elting Family ET
AB/VA Swapps = ABLA/VASC, Swapps Family ET
AB/VA Marosa = ABLA/VASC, Marosa Family ET
AB/VA McCall = ABLA/VASC, McCall Family ET
PIAL Marosa = PIAL Series, Marosa Family ET
PI/CA Como = PIAL/CARO5, Como Family ET
PI/CA Frisco = PIAL/CARO5, Frisco Family ET
PI/VA Elting = PIAL/VASC, Elting Family ET
PI/VA Jeru = PIAL/VASC, Jeru Family ET
PI/VA Sig = PIAL/VASC, Sig Family ET
PI/VA Salt Chuck = PIAL/VASC, Salt Chuck Family ET

Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
ABLA	DO	80 | 20	--	50 | 10	--	50 | 10	33 | 3	100 | 3	25 | 10	29 | 8	--	--	--	--	--	--	14 | 3
PIAL	DO	20 | 5	33 | 15	--	--	100 | 8	67 | 10	50 | 5	25 | 8	57 | 14	100 | 15	57 | 11	75 | 10	100 | 30	91 | 16	100 | 25	43 | 9
PICOL	DO	60 | 10	67 | 8	--	--	--	83 | 11	--	100 | 14	29 | 12	50 | 1	71 | 17	100 | 10	--	45 | 10	--	100 | 10
PIEN	DO	20 | 3	--	--	100 | 15	100 | 8	50 | 10	100 | 22	12 | 15	100 | 14	--	--	--	--	91 | 6	100 | 1	14 | 10
PIFL2	DO	20 | 5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PSMEG	DO	40 | 2	--	100 | 21	--	--	--	--	--	--	50 | 3	--	--	--	--	--	--
ABLA	SD	100 | 12	100 | 4	100 | 4	100 | 5	--	50 | 4	50 | 10	62 | 6	100 | 2	--	--	--	--	18 | 3	--	14 | 3
PIAL	SD	20 | 3	67 | 8	--	--	50 | 5	83 | 5	50 | 5	50 | 5	57 | 9	50 | 20	57 | 10	100 | 5	100 | 10	82 | 12	100 | 10	57 | 6
PICOL	SD	--	100 | 5	50 | 3	--	--	50 | 7	--	62 | 4	43 | 2	50 | 35	71 | 11	100 | 8	--	27 | 4	--	86 | 11
PIEN	SD	--	33 | 1	--	100 | 10	50 | 25	67 | 8	100 | 2	12 | 5	71 | 6	--	--	25 | 5	--	45 | 4	--	14 | 3
PIFL2	SD	20 | 1	--	100 | 6	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
POTR5	SD	60 | 3	33 | 1	--	--	--	--	--	12 | 5	--	--	--	--	--	--	--	14 | 3

Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
PSMEG	SD	--	--	25 | 5	--	--	--	--	--	--	--	--	--	--	--	--	--
ABLA	U	100 | 10	100 | 5	100 | 3	100 | 10	100 | 10	83 | 5	100 | 3	88 | 6	100 | 5	--	--	25 | 1	--	36 | 2	--	29 | 2
JUSC2	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 3
PIAL	U	--	100 | 9	--	--	100 | 6	83 | 2	--	50 | 2	86 | 2	100 | 1	100 | 6	100 | 7	100 | 7	82 | 4	100 | 3	86 | 3
PICOL	U	20 | 5	100 | 2	25 | 1	--	--	17 | 3	50 | 3	75 | 2	29 | 1	50 | 1	100 | 2	100 | 2	--	27 | 2	--	86 | 3
PIEN	U	--	--	--	--	100 | 4	50 | 2	50 | 1	25 | 3	86 | 2	--	--	25 | 3	100 | 3	64 | 1	--	--
PIFL2	U	--	--	100 | 5	--	--	--	--	--	--	--	--	--	--	--	--	--
POTR5	U	20 | 3	33 | 15	--	--	--	--	--	12 | 3	--	50 | 3	--	--	--	--	--	--
PSMEG	U	--	--	100 | 4	--	--	--	--	--	--	--	--	--	--	--	--	--
ABLA	SEED	100 | 10	100 | 8	100 | 3	100 | 20	100 | 4	100 | 5	100 | 8	100 | 4	100 | 11	--	14 | 3	50 | 1	--	45 | 1	--	43 | 2
PIAL	SEED	--	100 | 6	--	--	100 | 5	100 | 2	100 | 2	50 | 1	100 | 3	100 | 2	100 | 3	100 | 4	100 | 5	100 | 4	100 | 3	100 | 3
PICOL	SEED	20 | 1	100 | 1	--	--	--	50 | 2	--	100 | 2	29 | 1	50 | 1	100 | 1	75 | 2	--	18 | 1	--	86 | 2
PIEN	SEED	--	67 | 1	--	100 | 1	100 | 1	67 | 2	100 | 3	25 | 3	100 | 2	--	--	25 | 1	100 | 3	82 | 2	--	14 | 1
PIFL2	SEED	--	--	50 | 6	--	--	--	--	38 | 2	--	--	--	--	--	--	--	--
POTR5	SEED	60 | 2	67 | 4	--	--	--	--	--	12 | 1	--	50 | 1	14 | 1	--	--	--	--	14 | 1
PSMEG	SEED	--	--	100 | 2	--	--	--	--	--	--	--	--	--	--	--	--	--
ACGL	S	--	--	--	--	--	--	--	--	--	50 | 3	--	--	--	--	--	--
AMAL2	S	--	--	--	--	--	--	--	--	--	50 | 1	--	--	--	--	--	--
ARTRV2	S	--	--	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
ARUV	S	--	67 | 4	--	--	--	--	--	12 | 1	--	--	14 | 1	50 | 2	--	--	--	--
CEVE	S	--	--	25 | 10	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
CHUMO	S	20 | 1	--	--	--	--	--	--	--	--	50 | 1	--	--	--	--	--	--
JUCOD	S	20 | 1	100 | 4	100 | 7	--	--	50 | 3	--	62 | 4	14 | 10	100 | 3	14 | 3	50 | 1	100 | 5	45 | 4	--	43 | 2
LOIN5	S	--	--	--	--	--	--	--	--	--	50 | 1	--	--	--	--	--	14 | 1
MARE11	S	40 | 6	67 | 2	100 | 3	--	--	17 | 1	--	38 | 2	--	50 | 1	14 | 1	--	--	--	--	--
PHEM	S	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--	--	--
PUTR2	S	--	67 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RIBES	S	--	--	--	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
RICEP	S	--	33 | 1	--	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
RILA	S	--	--	--	--	--	17 | 1	--	--	14 | 1	--	--	--	--	--	--	14 | 1
RIMO2	S	--	--	--	100 | 10	100 | 5	--	--	--	--	--	--	--	--	--	--	--
RIVI3	S	--	33 | 1	--	--	--	--	--	12 | 1	--	50 | 1	--	--	--	--	--	--
ROSA3	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
ROWO	S	20 | 1	33 | 1	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
SACE3	S	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--	--	--
SAGLV	S	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	18 | 2	--	--
SAMBU	S	--	--	--	--	--	17 | 1	--	--	--	--	--	--	--	--	--	--
SAPL2	S	--	--	--	--	100 | 4	--	--	--	--	--	--	--	--	--	--	--

Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
SARA2	S	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SHCA	S	60 | 5	100 | 4	100 | 12	--	--	33 | 1	--	50 | 6	--	50 | 15	--	25 | 1	--	--	--	43 | 7
SYORU	S	40 | 2	33 | 1	25 | 1	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
VASC	S	--	--	--	100 | 1	--	100 | 23	100 | 55	75 | 26	100 | 37	100 | 22	--	--	100 | 50	100 | 50	100 | 1	100 | 34
ACMIL3	F	--	33 | 1	100 | 1	--	--	17 | 3	--	12 | 1	--	--	14 | 1	25 | 1	100 | 1	45 | 1	--	14 | 1
AGGL	F	--	--	50 | 1	--	--	--	--	25 | 1	--	--	29 | 1	25 | 1	--	--	--	--
ANEMO	F	--	--	25 | 3	--	--	--	--	--	--	--	--	--	--	--	--	--
ANMA	F	--	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
ANME2	F	--	--	--	--	100 | 4	--	--	--	14 | 3	--	--	--	--	18 | 2	--	--
ANPAM	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
ANRA	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
ANRO2	F	--	--	--	--	--	--	--	--	--	--	57 | 2	25 | 1	--	9 | 1	--	--
ANSES	F	--	--	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
ANTEN	F	--	33 | 1	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
ANUM	F	--	67 | 5	--	--	--	17 | 1	50 | 1	12 | 3	--	--	29 | 3	--	--	27 | 1	100 | 3	--
AQCO	F	20 | 1	--	50 | 3	100 | 1	--	33 | 1	--	--	43 | 1	--	--	--	--	18 | 1	--	14 | 1
ARCO9	F	100 | 7	33 | 3	100 | 5	100 | 1	--	83 | 3	100 | 8	100 | 5	100 | 4	100 | 2	57 | 2	50 | 1	100 | 3	82 | 4	100 | 1	100 | 2
ARLA8	F	--	--	--	--	--	17 | 1	--	--	--	--	--	25 | 1	--	9 | 1	--	--
ARRY	F	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 3	--	--
ARSC	F	--	--	--	--	100 | 4	--	--	--	14 | 1	--	--	--	--	18 | 1	--	--
ASAL7	F	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	9 | 1	--	--
ASAUG	F	20 | 20	--	50 | 3	--	--	--	--	--	--	--	--	--	--	--	--	--
ASEU2	F	--	--	--	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
ASKE	F	--	67 | 2	--	--	50 | 1	--	--	--	--	--	29 | 2	--	--	--	100 | 1	--
ASMI9	F	--	--	25 | 1	--	--	--	--	--	--	--	29 | 2	--	--	--	--	--
ASTER	F	20 | 1	--	--	--	--	--	--	--	--	50 | 1	--	--	--	--	--	--
ASTRA	F	--	--	25 | 3	--	--	--	--	--	--	--	--	--	--	--	--	--
BAIN	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
BASA3	F	--	--	25 | 3	--	--	--	--	--	--	--	--	--	--	--	--	--
BOAN6	F	--	--	25 | 1	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
BOEX2	F	--	33 | 1	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
BOEHOL	F	--	--	--	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
BOLY	F	--	--	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
BOWI	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
CALI4	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
CARO2	F	40 | 2	--	100 | 1	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
CASTI2	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
CHAN9	F	40 | 1	--	25 | 1	100 | 1	50 | 5	50 | 1	100 | 1	88 | 1	43 | 1	100 | 1	--	--	100 | 1	45 | 1	--	43 | 1

Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
CIRSI	F	--	--	--	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
CLMU5	F	--	--	--	--	--	--	--	12 | 1	--	50 | 3	--	--	--	--	--	--
COPA3	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
COTR3	F	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COWI2	F	--	--	--	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
CRAC2	F	--	--	25 | 1	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
CYLO10	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
DRCR2	F	--	--	--	100 | 1	--	--	--	--	--	--	--	--	--	--	--	--
ERAS2	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
ERCO24	F	--	67 | 1	50 | 1	--	--	17 | 1	--	25 | 1	--	--	57 | 2	25 | 1	100 | 1	27 | 1	100 | 1	--
ERCO5	F	--	--	--	--	100 | 4	--	--	--	--	--	--	--	--	--	--	--
ERCOD	F	--	--	--	--	--	17 | 1	--	--	--	--	14 | 1	--	--	--	--	--
ERFO3	F	--	--	--	--	50 | 3	--	--	--	--	--	--	--	--	--	--	--
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EROC	F	--	--	--	--	50 | 1	--	--	--	14 | 3	--	29 | 2	--	--	--	--	--
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ERSI3	F	--	--	--	--	50 | 3	--	--	--	--	--	--	--	--	9 | 1	--	--
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EUEL2	F	--	33 | 3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EUIN9	F	--	--	--	100 | 1	50 | 3	--	100 | 2	--	29 | 6	--	--	--	--	9 | 1	--	--
FRSP	F	--	--	100 | 2	--	--	17 | 1	--	--	--	--	--	25 | 1	100 | 1	--	100 | 1	--
FRVE	F	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
FRVI	F	20 | 1	33 | 1	50 | 2	--	--	--	--	12 | 1	--	--	--	--	--	--	--	--
GABO2	F	40 | 2	--	100 | 2	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--
GEROT	F	--	--	--	--	100 | 2	--	--	--	--	--	--	--	--	--	--	--
GETR	F	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GEVI2	F	60 | 2	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
HEALA	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
HIAL2	F	--	--	--	--	--	--	--	--	14 | 3	--	--	--	--	--	--	--
HITRG2	F	20 | 1	--	--	--	--	17 | 1	100 | 3	62 | 1	29 | 1	--	--	--	--	45 | 1	--	--
IVGO	F	--	--	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
LEPY2	F	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	--	100 | 1	14 | 1

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Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
PYPI2	F	--	--	--	--	--	--	--	--	--	50 | 1	--	--	--	--	--	14 | 1
SARH2	F	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
SEFR3	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
SEIN2	F	--	--	--	--	50 | 1	--	--	--	--	--	29 | 1	--	--	--	--	--
SELA	F	--	100 | 1	25 | 1	--	50 | 1	--	50 | 1	--	--	--	14 | 1	25 | 1	--	9 | 1	100 | 1	--
SENEC	F	--	--	25 | 1	--	--	--	--	--	--	50 | 1	--	--	--	--	--	--
SERA	F	--	--	25 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--
SESE2	F	--	--	--	100 | 1	--	--	--	--	--	--	--	--	--	--	--	--
SEST2	F	--	--	--	--	--	17 | 1	--	--	--	--	--	--	--	--	--	--
SIAN2	F	--	--	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--
SIPR	F	--	--	--	--	--	--	--	--	--	--	--	--	--	18 | 1	--	14 | 1
SOMUS	F	--	--	75 | 1	--	50 | 3	50 | 1	--	38 | 2	14 | 1	--	14 | 1	50 | 1	--	27 | 1	--	43 | 1
STELL	F	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--
SWPE	F	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SYFO2	F	20 | 1	--	75 | 1	--	--	--	--	12 | 1	--	--	--	--	100 | 1	9 | 1	--	--
TAER2	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 1	--	--	--
TAOF	F	20 | 1	--	75 | 1	--	--	--	--	25 | 1	--	--	--	--	--	--	--	--
THALI2	F	--	--	--	--	--	17 | 1	--	--	--	--	--	--	--	--	--	--
TOLY	F	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--
TRAL8	F	--	--	--	--	--	--	50 | 1	--	14 | 1	--	--	--	--	--	--	--
VIOLA	F	--	--	25 | 1	--	--	--	--	25 | 1	--	--	--	--	--	18 | 1	--	--
ACOC3	G	--	33 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BRIN2	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
BROMU	G	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
CAIN	G	--	--	--	--	--	17 | 1	--	--	--	--	--	--	--	--	--	14 | 1
CAST36	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
DECE	G	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--
ELEL5	G	--	67 | 1	--	--	--	--	--	12 | 1	--	--	29 | 2	25 | 1	100 | 1	9 | 1	--	14 | 1
ELGL	G	20 | 1	--	25 | 1	--	--	--	--	12 | 3	--	--	--	--	--	--	--	--
ELTR3	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 3	--	--
FEBR	G	--	33 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
FEID	G	--	33 | 1	--	--	--	--	--	--	--	--	57 | 2	--	--	9 | 1	--	--
FESA	G	--	--	--	--	50 | 1	--	--	--	14 | 1	--	--	--	--	--	--	--
KOMA	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
LEKI2	G	--	33 | 1	100 | 1	--	--	--	--	--	--	--	14 | 3	--	--	--	--	--
PHAL2	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
PIEX3	G	--	67 | 1	--	--	--	--	--	--	--	--	14 | 1	25 | 1	--	--	--	--
PIMI7	G	--	33 | 3	--	--	--	--	--	--	--	--	43 | 1	--	--	--	--	--

Ecological type		AB/AR-CAD Hierro	ABLA Elting	AB/MA Frisco	AB/RI Cranbay	AB/RI Elting	AB/VA Elting	AB/VA Swapps	AB/VA Marosa	AB/VA McCall	PIAL Marosa	PI/CA Como	PI/CA Frisco	PI/VA Elting	PI/VA Jeru	PI/VA Sig	PI/VA Salt Chuck
Species	**LF**	n=5	n=3	n=4	n=1	n=2	n=6	n=2	n=8	n=7	n=2	n=7	n=4	n=1	n=11	n=1	n=7
POA	G	--	--	--	--	--	--	--	--	--	50 | 1	14 | 3	--	--	--	--	14 | 1
POAR21	G	--	--	--	--	--	17 | 3	--	--	--	--	--	--	--	--	--	--
POCU2	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 3	--	--
POCU3	G	--	--	--	100 | 1	100 | 4	--	50 | 1	12 | 1	29 | 2	--	--	--	100 | 3	9 | 3	--	--
POFE	G	20 | 1	--	25 | 1	--	--	17 | 1	50 | 1	12 | 1	--	--	--	--	--	27 | 2	--	29 | 1
POPA3	G	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
POPR	G	--	--	--	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
POSE	G	--	33 | 1	25 | 1	--	50 | 5	17 | 1	--	--	--	--	29 | 2	25 | 1	100 | 1	27 | 2	100 | 1	14 | 1
POWH2	G	20 | 5	100 | 5	100 | 2	--	50 | 5	67 | 2	50 | 1	88 | 3	57 | 2	50 | 1	86 | 4	100 | 1	--	64 | 2	100 | 3	43 | 1
STIPA	G	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14 | 1
TRSP2	G	20 | 1	67 | 4	25 | 1	100 | 1	100 | 1	67 | 1	100 | 1	62 | 1	14 | 1	--	--	--	100 | 1	36 | 2	--	43 | 1
CALE9	GL	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
CAMA9	GL	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
CAPH2	GL	--	--	--	--	--	17 | 1	--	--	--	--	--	--	--	--	--	--
CAPY3	GL	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	--	--	--
CARA6	GL	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
CARO5	GL	40 | 1	33 | 5	50 | 1	100 | 1	50 | 1	83 | 2	100 | 3	88 | 2	86 | 2	100 | 1	100 | 3	100 | 1	--	64 | 3	100 | 3	57 | 2
CARU3	GL	20 | 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CASC10	GL	--	--	--	--	100 | 3	--	--	--	--	--	--	--	--	9 | 1	--	--
CASC12	GL	--	--	--	--	50 | 7	--	--	--	--	--	--	--	--	--	--	--
CASCP2	GL	--	--	--	--	50 | 5	--	--	--	--	--	--	--	--	--	--	--
CAXE	GL	--	--	--	--	50 | 5	--	--	--	--	--	--	--	--	--	--	--
JUDR	GL	--	--	--	--	--	--	--	--	14 | 1	--	--	--	--	--	--	--
JUPA	GL	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
LUMU2	GL	--	--	--	--	--	--	--	--	--	--	--	--	--	9 | 1	--	--
LUSP4	GL	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--	9 | 1	--	--

Appendix 8-2: Constancy and average cover of all species present in the following ecological types:

PI/JU Como = PIFL2/JUCOD, Como Family ET
PI/JU Lolo = PIFL2/JUCOD, Lolo Family ET
PI/JU Tyzak = PIFL2/JUCOD, Tyzak Family ET
PI/LE Saddlehorse = PIFL2/LEKI2, Saddlehorse Family ET
PS/AC Yourame = PSMEG/ACGL, Yourame Family ET
PS/AC Redfist = PSMEG/ACGL, Redfist Family ET
PS/JU Shawmut = PSMEG/JUCOD, Shawmut Family ET
PS/MA Cloud Peak = PSME/MARE11, Cloud Peak Family ET
PS/SY Typic Calc = PSMEG/SYORU, Typic Calciustepts ET

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
PIAL	DO	100 ǀ 1	--	--	--	--	--	--	--	--
PICOL	DO	100 ǀ 10	--	--	--	--	--	--	17 ǀ 25	--
PIFL2	DO	100 ǀ 5	100 ǀ 18	100 ǀ 18	100 ǀ 23	--	--	60 ǀ 35	17 ǀ 25	100 ǀ 8
PSMEG	DO	--	25 ǀ 5	50 ǀ 7	33 ǀ 10	100 ǀ 30	100 ǀ 20	100 ǀ 15	83 ǀ 30	100 ǀ 28
ABLA	SD	--	25 ǀ 3	--	--	--	17 ǀ 5	--	--	--
JUSC2	SD	--	--	17 ǀ 3	--	--	--	--	--	50 ǀ 1
PICOL	SD	--	--	--	--	--	33 ǀ 3	20 ǀ 3	--	--
PIFL2	SD	--	50 ǀ 8	--	33 ǀ 5	--	50 ǀ 4	80 ǀ 8	50 ǀ 2	50 ǀ 5
POTR5	SD	--	--	--	--	--	50 ǀ 10	--	--	--
PSMEG	SD	--	25 ǀ 3	--	33 ǀ 3	--	33 ǀ 10	80 ǀ 6	83 ǀ 20	100 ǀ 5
ABLA	U	--	25 ǀ 3	17 ǀ 1	--	--	--	--	--	--
JUSC2	U	--	--	--	--	--	--	20 ǀ 1	--	--
PICOL	U	100 ǀ 3	--	--	--	--	--	--	17 ǀ 3	--
PIFL2	U	100 ǀ 3	100 ǀ 4	83 ǀ 3	100 ǀ 6	--	50 ǀ 2	100 ǀ 5	67 ǀ 2	50 ǀ 1
POTR5	U	--	--	--	33 ǀ 1	--	33 ǀ 3	20 ǀ 3	--	50 ǀ 1
PSMEG	U	--	--	33 ǀ 2	--	100 ǀ 1	100 ǀ 4	80 ǀ 4	100 ǀ 5	100 ǀ 4
ABLA	SEED	--	25 ǀ 1	--	--	--	--	--	--	--
PICOL	SEED	100 ǀ 1	--	--	--	--	17 ǀ 1	--	17 ǀ 3	--
PIFL2	SEED	100 ǀ 1	100 ǀ 2	83 ǀ 2	100 ǀ 2	--	50 ǀ 2	100 ǀ 1	33 ǀ 2	50 ǀ 1
POTR5	SEED	100 ǀ 5	25 ǀ 1	--	33 ǀ 1	--	50 ǀ 2	20 ǀ 1	--	50 ǀ 1
PSMEG	SEED	--	50 ǀ 2	50 ǀ 1	33 ǀ 1	--	83 ǀ 4	100 ǀ 3	83 ǀ 2	100 ǀ 1
ACGL	S	--	25 ǀ 1	17 ǀ 1	--	100 ǀ 5	100 ǀ 6	60 ǀ 2	33 ǀ 2	100 ǀ 1
AMAL2	S	--	--	--	33 ǀ 1	100 ǀ 3	50 ǀ 2	--	17 ǀ 1	100 ǀ 1
ARFR4	S	--	--	17 ǀ 1	--	--	--	--	--	--
ARTRR4	S	--	--	--	--	--	17 ǀ 1	--	--	--
ARTRV2	S	100 ǀ 1	75 ǀ 17	83 ǀ 4	100 ǀ 32	--	--	60 ǀ 2	17 ǀ 1	--
CHVI8	S	--	25 ǀ 1	17 ǀ 3	--	--	--	--	--	--
ERNAN5	S	--	--	17 ǀ 1	--	--	--	--	--	--
HODU	S	--	--	17 ǀ 1	--	--	--	--	--	--

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
JUCOD	S	100 | 3	100 | 4	83 | 4	--	100 | 1	100 | 4	100 | 7	83 | 2	--
JUSC2	S	--	25 | 1	--	--	--	--	--	--	--
LOIN5	S	--	--	--	--	--	17 | 3	--	--	--
MARE11	S	100 | 1	75 | 1	50 | 1	--	100 | 5	100 | 6	80 | 2	100 | 5	50 | 1
PAMY	S	--	--	--	--	100 | 3	50 | 6	--	83 | 3	100 | 4
PEFL15	S	--	--	17 | 5	--	--	--	--	--	--
PRVIM	S	--	--	--	--	100 | 1	50 | 3	--	17 | 1	--
PUTR2	S	100 | 1	75 | 3	67 | 4	100 | 5	--	--	40 | 1	--	50 | 1
RIBES	S	--	--	--	--	--	17 | 3	--	--	--
RICEP	S	100 | 1	25 | 3	67 | 1	100 | 2	--	--	40 | 1	--	--
RILA	S	--	--	17 | 1	--	--	--	20 | 1	--	--
ROSA3	S	--	--	--	--	--	--	--	17 | 1	--
ROWO	S	100 | 1	25 | 1	50 | 1	--	100 | 1	100 | 2	40 | 1	50 | 1	50 | 1
RUID	S	100 | 1	--	--	--	--	--	--	--	--
SHCA	S	100 | 1	100 | 4	67 | 4	33 | 1	100 | 3	100 | 12	100 | 1	83 | 4	50 | 1
SYORU	S	100 | 3	100 | 2	83 | 2	67 | 4	100 | 15	83 | 5	100 | 3	67 | 2	100 | 10
ACMIL3	F	--	75 | 1	67 | 1	33 | 1	--	17 | 1	80 | 1	33 | 1	--
AGGL	F	--	50 | 1	33 | 2	67 | 2	--	--	40 | 1	--	--
ALCE2	F	--	--	33 | 1	--	--	--	--	--	--
ANCO	F	--	--	17 | 1	--	--	--	--	--	--
ANMA	F	--	50 | 1	--	--	--	--	20 | 1	17 | 1	--
ANMI3	F	--	--	17 | 1	--	--	17 | 1	--	--	--
ANPAM	F	--	--	--	--	--	--	40 | 1	17 | 1	--
ANRO2	F	100 | 1	--	17 | 1	--	--	33 | 1	20 | 1	--	--
ANTEN	F	--	--	--	33 | 1	--	--	--	--	--
ANUM	F	--	--	33 | 1	33 | 1	--	--	--	--	--
AQCO	F	--	--	--	--	--	33 | 2	20 | 1	33 | 1	--
ARCO9	F	100 | 1	50 | 1	17 | 1	--	100 | 25	100 | 11	80 | 9	100 | 3	100 | 3
ARLA8	F	--	--	--	--	--	17 | 1	--	--	--
ASAUG	F	--	--	17 | 1	--	--	--	20 | 5	33 | 6	100 | 2
ASMI9	F	--	50 | 2	67 | 3	67 | 2	--	--	20 | 1	--	--
ASTER	F	--	50 | 1	17 | 1	--	--	--	--	17 | 1	--
ASTRA	F	--	--	17 | 1	67 | 1	--	--	20 | 1	--	--
BAIN	F	--	50 | 3	67 | 7	--	--	--	--	17 | 1	--
BASA3	F	--	75 | 3	67 | 2	67 | 8	--	--	40 | 1	17 | 3	--
BOEX2	F	--	--	--	33 | 1	--	--	--	--	--
BOEHOL	F	100 | 1	--	17 | 1	--	--	--	--	--	--

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
BOFES	F	--	--	--	--	--	--	20 | 1	--	--
BOMI3	F	--	25 | 1	--	--	--	--	--	--	--
BONU	F	--	--	--	--	--	17 | 1	--	--	--
BOWI	F	--	--	--	--	--	17 | 1	--	--	--
BUAM2	F	--	25 | 1	33 | 1	--	--	--	20 | 1	17 | 1	--
CALI4	F	100 | 1	25 | 1	33 | 1	--	--	33 | 1	--	--	--
CAMI2	F	--	--	17 | 1	33 | 1	--	--	--	--	--
CAPA25	F	--	25 | 1	50 | 1	33 | 1	--	--	--	--	--
CAPIL	F	--	--	--	--	--	17 | 1	--	--	--
CARO2	F	--	25 | 1	17 | 1	--	--	17 | 1	40 | 2	17 | 1	--
CASTI2	F	--	50 | 1	--	--	--	--	--	--	--
CHAN9	F	--	--	17 | 1	--	--	17 | 1	20 | 1	17 | 5	--
CIRSI	F	--	--	50 | 1	33 | 1	--	--	40 | 1	--	--
CISU	F	--	25 | 1	--	--	--	--	20 | 1	--	--
COPA3	F	--	50 | 1	33 | 1	100 | 1	--	--	--	--	--
CRAC2	F	--	50 | 1	50 | 1	67 | 1	--	--	40 | 1	17 | 1	--
CREPI	F	--	--	17 | 1	--	--	--	--	--	--
CRIN4	F	--	25 | 3	--	33 | 1	--	--	--	--	50 | 1
CYEV	F	--	25 | 1	--	--	--	--	--	--	--
CYLO10	F	--	25 | 1	--	--	--	--	100 | 5	--	50 | 1
CYMOP2	F	--	--	--	--	--	--	--	17 | 1	--
CYTEA	F	--	50 | 3	83 | 2	67 | 2	--	--	20 | 1	--	50 | 1
DELPH	F	--	--	17 | 1	--	--	--	--	--	--
DENU2	F	--	25 | 1	33 | 1	33 | 1	--	--	--	--	--
DOCO	F	--	25 | 1	--	--	--	--	--	--	--
DODEC	F	--	--	17 | 1	--	--	--	--	--	--
DROL	F	--	--	33 | 1	33 | 1	--	--	20 | 1	--	--
DRPA	F	--	--	17 | 1	--	--	--	--	--	--
ERAS2	F	--	--	50 | 1	100 | 1	--	--	--	--	--
ERCA2	F	--	--	17 | 1	--	--	--	--	--	--
ERCO24	F	--	25 | 1	50 | 2	33 | 1	--	--	--	17 | 1	--
ERCO5	F	--	25 | 1	17 | 1	--	--	--	--	--	--
ERCOD	F	--	25 | 1	--	--	--	--	--	--	--
EREA	F	--	--	17 | 5	--	--	17 | 1	40 | 1	17 | 1	--
ERHOH2	F	--	--	17 | 3	--	--	--	--	--	--
ERIGE2	F	--	--	--	--	--	33 | 1	20 | 1	--	--
ERLA	F	--	--	17 | 1	--	--	--	--	--	--

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
ERLI	F	--	--	17 | 1	--	--	--	--	--	--
ERNA5	F	--	--	--	--	--	--	20 | 1	--	--
EROC	F	--	--	--	--	--	--	20 | 1	--	--
EROV	F	--	25 | 1	50 | 1	--	--	--	--	--	--
ERPU2	F	--	--	17 | 1	--	--	--	--	--	--
ERTW	F	--	--	--	--	--	--	--	17 | 1	--
ERUM	F	--	50 | 1	67 | 1	100 | 1	--	--	--	--	--
EUEL2	F	--	25 | 3	--	--	--	17 | 1	--	17 | 1	--
EUGL13	F	--	--	--	--	--	17 | 1	--	33 | 1	--
FRAT	F	--	25 | 1	--	--	--	--	--	--	--
FRSP	F	--	--	17 | 1	--	--	50 | 2	40 | 1	33 | 1	50 | 1
FRVE	F	--	--	--	--	--	--	20 | 1	17 | 1	--
FRVI	F	--	--	--	--	100 | 1	100 | 2	--	50 | 1	50 | 1
GABO2	F	--	75 | 6	33 | 2	--	100 | 1	100 | 2	60 | 1	67 | 2	100 | 1
GERAN	F	--	25 | 1	17 | 1	--	--	--	--	--	--
GEUM	F	--	--	--	--	100 | 1	17 | 1	--	--	--
GEVI2	F	--	--	--	--	--	33 | 1	--	17 | 1	--
HEALA	F	--	--	--	--	--	--	20 | 3	--	--
HEPA11	F	--	--	17 | 1	33 | 1	100 | 1	83 | 1	60 | 1	--	--
HEUN	F	--	--	17 | 2	--	--	--	--	--	--
IPSP	F	--	75 | 1	--	67 | 1	--	--	--	--	--
LEFR4	F	--	25 | 1	17 | 1	33 | 1	--	--	40 | 1	--	--
LERE7	F	--	--	17 | 1	--	--	--	--	--	--
LILE3	F	--	--	50 | 1	--	--	--	--	--	--
LIRU4	F	--	--	17 | 1	--	--	--	--	--	--
LOOR	F	--	25 | 1	33 | 1	67 | 1	--	--	--	--	--
LOTR2	F	--	25 | 1	33 | 2	33 | 1	--	--	--	17 | 1	--
LUAR3	F	--	--	--	--	--	17 | 1	--	--	--
LUPO2	F	--	--	17 | 3	33 | 3	--	--	--	--	--
MACA2	F	--	--	--	--	--	17 | 1	--	--	--
MEVI4	F	--	75 | 1	67 | 1	100 | 2	--	--	40 | 1	--	--
MINU4	F	--	--	--	33 | 1	--	--	20 | 1	--	--
MIOB2	F	--	--	17 | 1	--	--	--	--	--	--
ORSE	F	--	--	--	--	--	50 | 2	--	33 | 1	--
ORTO	F	--	--	17 | 1	--	--	--	--	--	--
OSBE	F	--	25 | 1	--	--	--	--	--	17 | 1	--
OSDE	F	--	--	--	--	--	33 | 2	20 | 1	33 | 1	--

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
OXSE	F	--	--	17 | 1	67 | 1	--	--	--	--	--
PACA15	F	--	50 | 1	67 | 1	100 | 1	--	--	--	17 | 1	--
PAST10	F	--	--	--	--	--	50 | 1	--	--	--
PEHU	F	--	50 | 1	67 | 1	67 | 1	--	--	20 | 1	17 | 1	--
PENST	F	--	--	--	33 | 1	--	--	--	--	--
PHHA	F	--	--	--	--	--	17 | 1	--	--	--
PHHO	F	--	25 | 1	50 | 2	33 | 1	--	--	--	--	--
PHMU3	F	--	75 | 2	83 | 4	100 | 2	--	--	60 | 1	17 | 1	--
POBR5	F	--	--	17 | 1	33 | 1	--	--	--	--	--
POCO13	F	--	--	--	--	--	--	80 | 1	17 | 1	--
PODI2	F	--	--	--	--	--	--	20 | 1	17 | 1	--
POGL9	F	100 | 3	--	--	--	--	50 | 1	--	--	--
POGR9	F	--	--	--	--	--	17 | 1	--	--	--
POOV2	F	--	50 | 1	67 | 2	--	--	--	20 | 1	--	--
POPE8	F	--	--	--	33 | 1	--	--	--	--	--
POTEN	F	--	--	--	--	--	33 | 1	20 | 1	17 | 1	--
PRTR4	F	--	--	--	--	100 | 1	17 | 1	--	--	--
SEFR3	F	--	--	--	--	--	--	40 | 1	--	--
SEIN2	F	--	50 | 2	33 | 2	100 | 2	--	--	--	--	--
SELA	F	--	75 | 1	67 | 1	--	--	--	--	--	--
SELU	F	--	--	17 | 2	--	--	--	--	--	--
SERA	F	--	--	--	--	--	--	20 | 1	17 | 1	--
SOMO	F	100 | 1	--	--	--	--	--	--	--	--
SOMUS	F	--	--	17 | 3	--	--	17 | 1	80 | 1	33 | 1	--
STAC	F	--	25 | 3	17 | 1	--	--	--	20 | 1	--	--
STST5	F	--	--	17 | 3	--	--	--	--	--	--
SWPE	F	--	25 | 1	--	--	--	--	--	17 | 1	--
SYFO2	F	--	--	17 | 1	--	100 | 3	100 | 4	60 | 1	50 | 1	100 | 1
TAER2	F	--	--	17 | 1	33 | 1	--	--	--	--	--
TAOF	F	--	--	--	67 | 1	--	17 | 1	40 | 1	--	--
TEACA2	F	--	25 | 1	17 | 1	--	--	--	20 | 1	--	--
TOSP	F	--	--	17 | 1	--	--	--	--	--	--
VIOLA	F	--	25 | 1	17 | 1	67 | 2	--	67 | 1	--	33 | 1	--
ZIPA2	F	--	--	17 | 1	--	--	--	--	--	--
ZIVEG	F	--	50 | 1	17 | 1	--	--	--	--	--	--
ACNE9	G	--	--	--	--	--	--	20 | 3	50 | 1	--
ELEL5	G	100 | 1	25 | 1	--	--	--	33 | 1	--	--	--

Ecological Type		PI/JU Como	PI/JU Lolo	PI/JU Tyzak	PI/LE Saddlehorse	PS/AC Yourame	PS/AC Redfist	PS/JU Shawmut	PS/MA Cloud Peak	PS/SY Typic Calc
Species	**LF**	n=1	n=4	n=6	n=3	n=1	n=6	n=5	n=6	n=2
ELGL	G	--	--	--	--	--	50 | 4	--	--	--
ELSM3	G	--	--	--	--	--	17 | 1	--	--	--
ELSP3	G	--	50 | 1	67 | 2	100 | 4	--	--	--	17 | 1	--
ELTR7	G	--	--	--	--	--	--	20 | 1	--	--
FEID	G	--	50 | 2	17 | 5	67 | 1	--	--	--	17 | 1	--
HECOC9	G	--	25 | 1	--	--	--	--	--	--	--
KOMA	G	--	--	17 | 1	--	--	--	--	--	--
LEKI2	G	--	100 | 4	83 | 4	100 | 5	--	67 | 2	100 | 2	17 | 1	50 | 1
POA	G	--	25 | 1	--	--	--	--	--	--	--
POAR21	G	--	--	--	--	--	17 | 1	--	--	--
POFE	G	--	25 | 3	17 | 5	33 | 3	--	33 | 3	60 | 1	17 | 1	50 | 1
POGR	G	--	--	--	--	--	33 | 1	--	--	--
POSE	G	100 | 1	100 | 2	67 | 3	100 | 7	--	--	60 | 1	--	--
POWH2	G	100 | 3	25 | 1	--	--	100 | 1	83 | 3	--	83 | 1	50 | 1
TRSP2	G	--	--	--	--	--	67 | 2	20 | 1	17 | 1	--
CAGE2	GL	--	--	17 | 3	--	--	17 | 1	--	--	--
CANA2	GL	--	--	--	33 | 15	--	--	--	--	--
CAOB4	GL	--	--	67 | 2	--	--	--	--	--	--
CAREX	GL	--	25 | 1	--	--	--	17 | 1	--	--	--
CARO5	GL	100 | 3	50 | 3	17 | 1	33 | 5	--	17 | 1	60 | 2	67 | 2	--

Appendix 8-3: Constancy and average cover of all species present in the following ecological types:

PI/AR Como = PICOL/ARCO9, Como Family ET
PI/CA Stecum = PICOL/CARO5, Stecum Family ET
PI/JU Holland Lake = PICOL/JUCOD, Holland Lake Family ET
PI/MA Agneston = PICOL/MARE11, Agneston Family ET
PI/SH Bohica = PICOL/SHCA, Bohica Family ET
PI/VA Telcher = PICOL/VASC, Telcher Family ET
PICO Corbly = PICOL Series, Corbly Family ET
PI/CA Targhee = PICOL/CARO5, Targhee Family ET

Ecological Type		PI/AR Como	PI/CA Stecum	PI/JU Holland Lake	PI/MA Agneston	PI/SH Bohica	PI/VA Telcher	PICO Corbly	PI/CA Targhee
Species	LF	n=6	n=1	n=2	n=5	n=2	n=2	n=4	n=3
PIAL	DO	--	--	--	--	50 I 5	--	--	--
PICOL	DO	100 I 33	100 I 20	100 I 28	100 I 19	100 I 10	100 I 22	100 I 21	100 I 23
PIEN	DO	--	--	--	--	--	--	--	33 I 1
POTR5	DO	--	--	--	--	--	--	25 I 5	--
PSMEG	DO	--	--	--	--	--	--	25 I 5	--
PIAL	SD	--	--	50 I 5	--	--	--	--	67 I 3
PICOL	SD	50 I 15	100 I 5	50 I 15	20 I 7	50 I 15	--	75 I 10	100 I 13
PIFL2	SD	17 I 3	100 I 3	--	--	--	--	75 I 4	--
POTR5	SD	17 I 3	--	50 I 3	--	--	50 I 3	25 I 15	--
PSMEG	SD	--	--	--	--	--	--	50 I 2	--
PIAL	U	--	--	50 I 1	--	50 I 1	--	--	--
PICOL	U	83 I 3	100 I 1	100 I 4	100 I 12	100 I 12	100 I 4	75 I 8	67 I 4
PIFL2	U	--	100 I 10	--	--	--	--	50 I 1	33 I 1
POTR5	U	--	--	--	20 I 20	50 I 3	50 I 5	50 I 5	--
PSMEG	U	--	--	--	20 I 1	--	--	--	--
PIAL	SEED	--	--	100 I 2	--	50 I 1	50 I 1	--	67 I 3
PICOL	SEED	83 I 1	100 I 3	100 I 4	80 I 5	100 I 1	100 I 1	75 I 2	100 I 5
PIEN	SEED	--	--	--	--	50 I 1	--	--	--
PIFL2	SEED	50 I 2	100 I 1	--	20 I 1	--	--	75 I 1	33 I 1
POTR5	SEED	--	100 I 1	50 I 1	20 I 15	50 I 1	50 I 1	75 I 2	--
PSMEG	SEED	--	100 I 1	--	--	--	--	25 I 1	--
AMAL2	S	33 I 1	--	--	--	--	--	--	--
ARTRV2	S	--	100 I 1	--	--	--	--	--	--
ARUV	S	--	--	100 I 8	--	100 I 1	--	25 I 1	33 I 3
CEVE	S	--	--	--	40 I 2	--	--	25 I 3	--
JUCOD	S	83 I 1	100 I 1	100 I 4	40 I 5	100 I 1	50 I 1	25 I 3	33 I 1
MARE11	S	33 I 1	100 I 1	50 I 1	100 I 3	--	100 I 1	75 I 4	--
PAMY	S	--	--	--	20 I 10	--	--	--	--
PRVIM	S	--	--	--	20 I 3	--	--	25 I 1	--

Ecological Type		PI/AR Como	PI/CA Stecum	PI/JU Holland Lake	PI/MA Agneston	PI/SH Bohica	PI/VA Telcher	PICO Corbly	PI/CA Targhee
Species	**LF**	n=6	n=1	n=2	n=5	n=2	n=2	n=4	n=3
PUTR2	S	--	100 | 1	--	--	--	--	50 | 2	--
RHART2	S	--	--	--	20 | 1	--	--	--	--
RIBES	S	--	--	--	--	--	50 | 1	--	--
RICEP	S	--	--	--	20 | 1	--	--	--	--
RILA	S	--	--	--	--	50 | 5	--	--	--
RIVI3	S	17 | 1	--	--	20 | 5	50 | 1	--	--	--
ROWO	S	--	--	50 | 1	40 | 1	--	--	--	--
RUID	S	--	--	--	20 | 3	--	--	--	--
SASC	S	--	--	--	20 | 1	50 | 3	--	--	--
SHCA	S	--	--	50 | 3	100 | 2	100 | 9	100 | 3	25 | 15	33 | 1
SYORU	S	17 | 1	100 | 1	--	--	--	--	25 | 1	--
VASC	S	--	--	--	--	--	100 | 24	--	--
ACMIL3	F	33 | 1	100 | 1	50 | 1	40 | 1	--	--	--	33 | 1
AGGL	F	--	--	--	40 | 1	--	--	25 | 1	33 | 1
ANCO	F	--	--	50 | 1	--	--	--	--	--
ANMI3	F	--	--	--	20 | 1	--	--	--	--
ANRO2	F	33 | 1	100 | 1	50 | 1	40 | 1	--	--	--	--
ANTEN	F	--	--	--	--	--	50 | 1	25 | 1	--
ANUM	F	--	--	--	40 | 3	--	--	50 | 2	100 | 1
APAN2	F	--	--	50 | 1	--	--	--	--	--
AQCO	F	--	--	--	--	50 | 1	--	--	--
ARCO9	F	100 | 9	--	100 | 3	100 | 5	50 | 1	100 | 6	50 | 4	67 | 1
ARRY	F	17 | 1	--	--	--	--	--	--	--
ASKE	F	--	100 | 3	--	--	--	--	--	33 | 1
ASTER	F	17 | 1	--	--	20 | 3	--	--	--	--
BOAN6	F	--	--	50 | 1	20 | 1	--	--	25 | 1	33 | 1
BOBR4	F	--	--	--	--	--	--	25 | 1	--
BOECH	F	17 | 1	--	--	--	--	--	--	--
BOEX2	F	--	--	--	--	--	--	25 | 1	--
BOWI	F	--	--	--	--	--	--	25 | 1	--
CARO2	F	50 | 1	--	100 | 1	20 | 5	50 | 1	50 | 1	25 | 1	33 | 1
CHAN9	F	33 | 1	--	50 | 3	40 | 1	--	--	--	--
CLMU5	F	17 | 1	--	--	--	--	--	--	--
COLI2	F	--	--	--	20 | 1	--	--	75 | 1	--
COPA3	F	--	--	50 | 1	20 | 1	--	--	75 | 1	--
COTR3	F	67 | 1	--	--	20 | 1	--	--	25 | 1	--
CRAC2	F	--	--	--	--	--	--	50 | 1	--

Ecological Type		PI/AR Como	PI/CA Stecum	PI/JU Holland Lake	PI/MA Agneston	PI/SH Bohica	PI/VA Telcher	PICO Corbly	PI/CA Targhee
Species	**LF**	n=6	n=1	n=2	n=5	n=2	n=2	n=4	n=3
CYMOP2	F	17 | 1	--	--	--	--	--	--	--
ERCO24	F	33 | 1	--	--	40 | 2	--	--	50 | 1	100 | 1
EREA	F	--	--	--	40 | 2	--	--	25 | 1	--
EROC	F	17 | 1	--	--	--	--	--	--	33 | 1
ERUM	F	17 | 1	100 | 1	--	--	--	--	50 | 1	--
EUEL2	F	--	--	--	20 | 1	--	--	--	--
EUGL13	F	50 | 2	100 | 1	--	20 | 1	--	--	25 | 1	--
FRVI	F	17 | 1	--	100 | 1	60 | 2	--	50 | 1	--	33 | 1
GABO2	F	--	--	--	--	--	50 | 1	--	--
GETR	F	--	--	--	--	--	--	--	33 | 1
GEVI2	F	--	--	--	20 | 1	--	--	--	--
HIAL2	F	--	--	50 | 3	80 | 2	--	--	--	33 | 1
HITRG2	F	67 | 1	--	--	20 | 1	--	50 | 3	25 | 1	--
IPSP	F	--	100 | 1	--	--	--	--	--	--
IVGO	F	--	--	--	--	--	--	--	33 | 1
LIGLR	F	17 | 1	--	--	--	--	--	--	--
LOMAT	F	--	--	--	--	--	--	25 | 1	--
LOTR2	F	33 | 1	100 | 1	--	--	--	--	25 | 1	--
LUAR3	F	--	--	100 | 2	20 | 5	50 | 3	--	75 | 1	67 | 1
LUPIN	F	--	100 | 1	--	--	--	--	--	--
LUPO2	F	--	--	--	--	--	--	--	33 | 1
LUSE4	F	--	--	--	20 | 5	--	--	25 | 3	--
ORSE	F	50 | 1	--	--	40 | 1	50 | 1	50 | 3	--	33 | 1
ORUNO2	F	--	--	50 | 1	--	--	--	--	--
OSBE	F	--	--	--	20 | 1	--	50 | 1	--	--
OSDE	F	--	--	--	40 | 2	--	--	25 | 1	67 | 1
OSMOR	F	--	--	--	--	--	50 | 1	--	--
OSPU	F	--	--	--	20 | 1	--	--	--	--
PEST2	F	--	--	50 | 1	--	--	--	25 | 1	--
PHMU3	F	17 | 1	100 | 1	--	--	--	--	50 | 1	33 | 1
PHSE	F	--	--	--	20 | 1	--	--	25 | 1	33 | 1
POAR7	F	17 | 1	--	50 | 1	20 | 1	--	--	--	33 | 1
POCO13	F	--	--	--	--	--	--	25 | 1	--
PODI2	F	--	--	--	--	--	--	--	100 | 1
POGL9	F	--	--	50 | 1	20 | 1	--	--	--	--
POTEN	F	33 | 1	--	--	20 | 1	50 | 1	--	--	--
PTAN2	F	--	--	--	--	--	50 | 1	--	--

Ecological Type		PI/AR Como	PI/CA Stecum	PI/JU Holland Lake	PI/MA Agneston	PI/SH Bohica	PI/VA Telcher	PICO Corbly	PI/CA Targhee
Species	**LF**	n=6	n=1	n=2	n=5	n=2	n=2	n=4	n=3
PYCH	F	17 | 1	--	100 | 1	20 | 1	50 | 1	--	--	--
PYMI	F	17 | 3	--	--	--	--	--	--	--
PYROL	F	17 | 1	--	--	--	--	--	--	--
SEIN2	F	--	--	--	--	--	--	50 | 2	--
SELA	F	50 | 1	--	50 | 1	20 | 1	--	--	--	33 | 1
SIDR	F	--	--	50 | 1	--	--	--	--	--
SOLID	F	--	--	--	--	--	50 | 1	--	--
SOMUS	F	33 | 1	--	100 | 1	20 | 7	50 | 1	--	--	100 | 2
SYFO2	F	17 | 3	--	100 | 6	20 | 1	--	--	--	--
TAER2	F	--	--	--	20 | 5	--	--	--	--
TAOF	F	--	--	--	--	--	--	50 | 1	--
THALI2	F	--	--	--	--	--	50 | 1	--	--
VIOLA	F	17 | 1	100 | 1	--	40 | 1	--	50 | 1	25 | 1	33 | 1
ACNE9	G	--	--	--	--	--	--	25 | 3	33 | 1
ACOC3	G	--	--	--	20 | 3	--	--	--	--
BRCI2	G	--	--	50 | 1	--	--	--	--	--
BRIN2	G	--	--	--	20 | 3	--	--	--	--
ELEL5	G	--	--	100 | 1	40 | 1	--	--	--	67 | 1
ELGL	G	--	--	50 | 3	--	--	--	--	--
ELTR7	G	--	--	50 | 1	--	--	--	--	--
FEID	G	--	--	--	20 | 1	--	--	75 | 2	--
FESA	G	--	--	--	--	--	--	--	33 | 1
LEKI2	G	--	--	50 | 1	--	--	--	--	--
MEBU	G	--	--	--	--	--	--	25 | 1	--
PIEX3	G	--	100 | 3	50 | 1	20 | 1	--	--	75 | 3	33 | 1
POA	G	--	--	--	--	--	50 | 1	--	--
POFE	G	--	--	--	--	--	--	--	33 | 1
POSE	G	--	100 | 1	--	--	50 | 1	--	25 | 1	--
POWH2	G	100 | 2	100 | 1	100 | 1	100 | 6	100 | 2	50 | 3	100 | 4	100 | 3
TRSP2	G	--	--	50 | 1	40 | 1	50 | 1	--	--	--
CARO5	GL	83 | 1	100 | 3	100 | 3	80 | 2	50 | 3	50 | 1	100 | 2	100 | 1

Appendix 8-4: Constancy and average cover of all species present in the following ecological types:

GEROT-CAEL3 Agneston = GEROT-CAEL3, Agenston Family ET
GEROT-turf McCall = GEROT-turf McCall Family ET
KRUMMHOLZ Klootch = Krummholz, Klootch Family ET
Late Snowbank DECE = Late Snowbank, Hargran Family ET- DECE Habitat Type
Late Snowbank JUPA = Late Snowbank, Hargran Family ET - JUPA Habitat Type
Late Snowbank SAGLV/DECE = Late Snowbank, Hargran Family ET - SAGLV/DECE Habitat Type
Late Snowbank SAREN2/CASC12 = Late Snowbank, Hargran Family ET - SAREN2/CASC12 Habitat Type
SAREN2/KOMY McCall = SAREN2/KOMY, McCall Family ET

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
PIAL	SEED	25 | 1	--	33 | 1	--	--	50 | 1	--	33 | 1
PIEN	SEED	--	--	--	--	--	50 | 1	--	--
ABLA	S	--	--	100 | 5	--	--	--	--	--
ARFR4	S	--	20 | 1	--	--	--	--	--	--
DROCH3	S	--	--	--	--	--	--	--	67 | 10
KAMI	S	--	--	--	50 | 1	--	--	--	--
PHEM	S	--	--	67 | 1	--	--	--	--	--
PIAL	S	--	20 | 1	100 | 9	--	--	--	--	--
PIEN	S	--	--	33 | 1	--	--	--	--	--
SAARP5	S	--	--	33 | 3	50 | 3	--	50 | 1	--	33 | 10
SABR	S	--	--	33 | 5	--	--	--	--	--
SAGLV	S	--	--	67 | 10	100 | 2	50 | 3	100 | 18	--	67 | 4
SAPL2	S	--	--	--	--	--	50 | 3	--	--
SAREN2	S	--	--	33 | 1	--	--	--	100 | 25	100 | 13
VASC	S	--	--	67 | 3	--	50 | 1	--	--	--
ACMIL3	F	50 | 1	--	33 | 3	--	50 | 1	--	--	--
AGGL	F	50 | 1	--	--	--	--	--	--	--
AGOSE	F	--	--	33 | 1	--	--	--	--	--
ANME2	F	--	20 | 1	67 | 2	50 | 1	50 | 1	--	100 | 5	33 | 1
ANMI3	F	--	--	33 | 1	--	--	--	--	--
ANSES	F	50 | 1	20 | 1	--	--	--	--	--	--
ANUM	F	50 | 1	40 | 3	33 | 1	50 | 1	50 | 3	--	--	--
AQCO	F	--	--	--	50 | 1	--	--	--	--
ARLA8	F	--	--	33 | 3	--	--	--	--	--
ARMO4	F	--	--	33 | 5	--	--	--	--	--

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
ARRY	F	--	--	33 ǀ 5	--	--	--	--	--
ARSC	F	75 ǀ 2	80 ǀ 4	100 ǀ 3	50 ǀ 3	100 ǀ 9	100 ǀ 3	100 ǀ 5	100 ǀ 5
ASAL7	F	--	--	--	--	--	--	--	33 ǀ 1
ASKE	F	--	--	33 ǀ 1	--	--	--	--	33 ǀ 1
ASTRA	F	--	40 ǀ 1	--	--	--	--	--	--
BEWY	F	25 ǀ 1	--	--	--	--	--	--	--
BOAN6	F	25 ǀ 1	20 ǀ 1	--	--	--	--	--	--
BUAM2	F	25 ǀ 1	20 ǀ 1	--	--	--	--	--	--
CALE4	F	--	--	--	100 ǀ 1	50 ǀ 1	--	--	--
CAPU10	F	--	20 ǀ 1	--	--	50 ǀ 1	--	--	--
CARH4	F	--	--	33 ǀ 1	--	50 ǀ 1	--	--	--
CARO2	F	25 ǀ 1	--	--	--	--	--	--	--
CASTI2	F	--	--	33 ǀ 1	--	--	--	--	--
CHAN9	F	--	--	33 ǀ 1	--	--	--	--	--
CYLO10	F	25 ǀ 5	--	--	--	--	--	--	--
CYNI3	F	25 ǀ 1	20 ǀ 3	--	--	--	--	--	--
DOPU	F	--	--	--	--	50 ǀ 1	--	--	--
DRAU	F	50 ǀ 1	20 ǀ 1	--	--	--	--	--	--
DRCA4	F	50 ǀ 1	--	--	--	--	--	--	--
DRIN2	F	--	20 ǀ 1	--	--	--	50 ǀ 1	--	--
DRLO	F	--	--	--	--	--	--	--	33 ǀ 1
EPCI	F	--	--	--	--	50 ǀ 1	--	--	--
EPHA	F	--	--	--	50 ǀ 1	--	--	--	--
EPILO	F	--	--	--	--	--	50 ǀ 1	--	--
ERCO24	F	25 ǀ 1	--	67 ǀ 2	--	100 ǀ 1	--	--	--
ERCOD	F	25 ǀ 1	20 ǀ 1	--	--	--	--	--	--
ERLA	F	--	40 ǀ 1	--	--	--	--	100 ǀ 1	--
ERLE6	F	--	--	--	--	50 ǀ 1	--	--	--
EROC	F	25 ǀ 3	20 ǀ 1	33 ǀ 1	--	--	--	--	--
EROV	F	25 ǀ 1	--	--	--	--	--	--	--
ERPES3	F	--	--	67 ǀ 3	50 ǀ 3	100 ǀ 8	--	100 ǀ 1	--
ERSI3	F	--	--	33 ǀ 3	--	100 ǀ 3	--	--	33 ǀ 1
ERUR2	F	--	--	--	--	--	50 ǀ 10	--	--
ERYSI	F	--	--	--	--	--	50 ǀ 1	--	--
FRSP	F	25 ǀ 1	--	--	--	--	--	--	--
GEAL2	F	--	--	--	50 ǀ 1	--	--	--	67 ǀ 1

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
GEAM3	F	--	--	--	50 | 1	--	--	--	--
GEROT	F	100 | 19	100 | 15	67 | 2	50 | 5	--	100 | 9	100 | 5	100 | 15
HITRG2	F	--	--	33 | 1	--	50 | 3	--	--	--
HYGR5	F	25 | 1	60 | 1	--	--	--	--	--	100 | 1
LEPY2	F	--	--	33 | 1	--	50 | 1	50 | 1	--	--
LOAT	F	--	--	33 | 1	--	--	--	--	--
MEAL7	F	--	--	--	--	--	50 | 1	--	--
MECI3	F	--	20 | 1	--	--	--	--	--	--
MINU4	F	--	--	--	--	--	50 | 3	--	--
MIOB2	F	50 | 3	60 | 3	33 | 1	--	--	50 | 1	--	33 | 3
NONI	F	50 | 1	--	--	--	50 | 1	--	--	--
ORAL4	F	--	40 | 2	33 | 1	--	100 | 1	--	100 | 3	--
OXCA4	F	25 | 1	40 | 4	--	--	--	--	--	33 | 5
OXDE2	F	25 | 1	--	--	--	--	--	--	--
OXLA2	F	25 | 1	--	--	--	--	--	--	--
OXPO	F	--	--	33 | 1	--	--	--	--	--
PACA15	F	--	--	33 | 1	--	--	--	--	--
PADI11	F	25 | 3	--	33 | 1	--	--	--	--	33 | 1
PAST10	F	25 | 1	20 | 1	--	--	--	--	--	--
PECO	F	--	--	--	--	--	--	100 | 3	--
PEDIC	F	--	--	33 | 1	--	--	--	--	--
PEGR2	F	--	--	--	--	50 | 1	--	--	--
PENST	F	25 | 1	--	--	--	--	--	--	--
PEPA3	F	--	20 | 1	33 | 1	--	--	--	--	--
PEPR2	F	--	20 | 1	33 | 1	--	--	--	--	--
PHHO	F	--	20 | 1	33 | 3	--	--	--	--	33 | 1
PHMU3	F	--	--	33 | 3	--	--	--	--	--
PHMU4	F	--	20 | 1	--	--	--	--	--	--
PHPU5	F	100 | 2	80 | 2	33 | 1	--	--	--	--	33 | 3
POBI6	F	75 | 2	100 | 2	100 | 3	100 | 1	100 | 3	100 | 2	100 | 3	67 | 1
PODI2	F	50 | 3	100 | 3	33 | 3	100 | 3	50 | 3	100 | 6	100 | 5	33 | 1
POGR9	F	50 | 3	--	67 | 5	--	100 | 2	--	--	67 | 3
POVI	F	50 | 1	40 | 1	--	--	--	--	--	33 | 3
POVI3	F	--	--	--	50 | 1	--	50 | 1	--	100 | 1
SARH2	F	50 | 1	40 | 1	67 | 1	--	50 | 3	50 | 1	--	33 | 1
SECR	F	--	--	33 | 1	--	--	50 | 1	--	67 | 1

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
SEIN4	F	--	--	--	--	--	--	--	33 ǀ 1
SELA	F	75 ǀ 2	80 ǀ 2	33 ǀ 1	--	--	--	--	33 ǀ 1
SENEC	F	--	20 ǀ 1	--	--	--	--	--	--
SERH	F	--	--	--	50 ǀ 1	--	--	--	--
SESE2	F	--	--	33 ǀ 1	--	--	--	--	--
SEST2	F	25 ǀ 3	20 ǀ 1	100 ǀ 3	--	--	50 ǀ 1	--	33 ǀ 1
SIACS2	F	25 ǀ 1	100 ǀ 1	33 ǀ 1	--	--	50 ǀ 1	--	100 ǀ 2
SIKI	F	50 ǀ 2	20 ǀ 1	--	--	--	--	--	--
SIPA4	F	--	20 ǀ 1	--	--	--	--	--	--
SIPR	F	--	20 ǀ 1	67 ǀ 1	100 ǀ 2	100 ǀ 4	--	--	--
SOMUS	F	50 ǀ 1	60 ǀ 2	67 ǀ 2	50 ǀ 1	50 ǀ 1	--	--	100 ǀ 3
STCA	F	25 ǀ 1	--	--	--	--	--	--	--
STLO2	F	--	--	--	--	--	50 ǀ 1	--	--
STMO2	F	--	--	33 ǀ 1	50 ǀ 1	--	--	--	33 ǀ 1
SYFO2	F	--	--	--	--	--	--	100 ǀ 3	--
TACE	F	--	--	--	--	--	--	--	33 ǀ 1
TAOF	F	25 ǀ 1	--	--	--	--	--	--	--
TOLY	F	--	20 ǀ 1	--	--	--	--	--	--
TRAL8	F	--	--	33 ǀ 1	--	--	--	--	--
TRDA2	F	25 ǀ 5	--	33 ǀ 1	--	--	--	--	--
TRNA2	F	75 ǀ 4	60 ǀ 5	33 ǀ 1	50 ǀ 1	--	50 ǀ 1	--	--
VERON	F	--	20 ǀ 1	--	--	--	--	--	--
VEWO2	F	--	--	33 ǀ 1	--	50 ǀ 1	--	--	--
CYFR2	FH	--	--	33 ǀ 1	--	--	--	--	--
AGHU	G	--	--	33 ǀ 1	--	--	--	--	--
AGID	G	--	--	33 ǀ 1	--	--	--	--	--
AGVA	G	--	20 ǀ 1	--	50 ǀ 1	--	50 ǀ 1	--	--
CAPU	G	100 ǀ 2	40 ǀ 6	67 ǀ 1	--	--	--	--	33 ǀ 3
CASC	G	--	--	33 ǀ 1	--	--	--	--	--
DAIN	G	--	--	33 ǀ 1	--	50 ǀ 1	--	--	--
DECE	G	--	20 ǀ 1	33 ǀ 3	100 ǀ 42	100 ǀ 3	100 ǀ 6	100 ǀ 3	33 ǀ 1
ELEL5	G	50 ǀ 2	20 ǀ 1	--	--	--	--	--	--
ELSM3	G	25 ǀ 5	--	--	--	--	--	--	--
ELTR7	G	75 ǀ 2	40 ǀ 2	33 ǀ 1	50 ǀ 1	--	--	--	--
FEBR	G	50 ǀ 3	60 ǀ 2	--	50 ǀ 1	--	50 ǀ 1	--	33 ǀ 1
FEID	G	25 ǀ 10	--	--	--	--	--	--	--

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
FESA	G	50 | 4	80 | 4	67 | 3	--	--	--	--	67 | 1
FEVIK2	G	--	--	--	--	--	--	--	33 | 1
KOMA	G	--	20 | 10	--	--	--	--	--	--
LEKI2	G	25 | 3	--	--	--	--	--	--	--
PHAL2	G	--	--	67 | 3	50 | 1	100 | 4	--	--	--
POAL2	G	25 | 3	20 | 1	67 | 1	--	50 | 1	--	--	--
POAR2	G	50 | 3	60 | 2	33 | 1	50 | 5	--	50 | 1	--	100 | 6
POCU3	G	--	--	67 | 6	--	--	--	--	--
POGLR	G	25 | 1	20 | 5	--	--	--	--	--	33 | 1
POLE3	G	--	--	--	--	100 | 2	--	--	--
POPA3	G	25 | 3	--	--	--	--	--	--	--
POSE	G	100 | 6	80 | 7	33 | 1	--	50 | 1	50 | 1	100 | 15	--
POWH2	G	--	--	33 | 1	--	--	--	--	--
TRSP2	G	75 | 2	80 | 2	100 | 1	50 | 1	100 | 1	50 | 1	--	100 | 2
CAAL6	GL	50 | 1	--	--	--	--	--	--	33 | 3
CAAT13	GL	25 | 1	--	--	--	--	--	--	--
CACA13	GL	--	20 | 3	33 | 3	--	--	--	--	--
CAEL3	GL	100 | 18	80 | 3	67 | 5	--	--	--	--	--
CALE9	GL	--	--	--	--	--	50 | 3	--	--
CAMA9	GL	50 | 1	40 | 2	--	100 | 2	100 | 3	50 | 1	--	--
CAMI10	GL	--	--	--	50 | 1	--	--	--	--
CAMI7	GL	--	--	33 | 1	--	--	--	--	--
CANE3	GL	--	--	--	50 | 3	--	--	--	--
CANI2	GL	--	--	33 | 1	--	50 | 1	--	--	--
CANOS2	GL	--	20 | 1	--	--	--	--	--	33 | 3
CAPA31	GL	--	20 | 5	33 | 10	--	--	--	--	33 | 5
CAPH2	GL	--	40 | 4	--	--	--	--	--	--
CARA6	GL	--	20 | 3	33 | 3	--	100 | 3	--	--	--
CAREX	GL	--	20 | 1	--	--	--	--	--	--
CARO5	GL	--	--	33 | 1	--	--	--	--	--
CARU3	GL	--	40 | 3	--	--	--	--	--	--
CASC10	GL	50 | 5	60 | 8	67 | 3	50 | 3	100 | 1	50 | 5	--	67 | 2
CASC12	GL	--	--	--	50 | 3	--	50 | 30	100 | 25	--
CASCP2	GL	--	--	33 | 3	--	50 | 1	--	--	--
JUDR	GL	--	--	33 | 3	--	--	--	--	--
JUPA	GL	--	--	--	--	100 | 25	--	--	--

Ecological Type		GEROT-CAEL3 Agneston	GEROT-turf McCall	KRUMMHOLZ Klootch	Late Snowbank DECE	Late Snowbank JUPA	Late Snowbank SAGLV/DECE	Late Snowbank SAREN2/CASC12	SAREN2/KOMY McCall
Species	**LF**	n=4	n=5	n=3	n=2	n=2	n=2	n=1	n=3
JUTR4	GL	--	--	--	--	--	--	100 | 1	--
KOMY	GL	--	--	--	--	--	--	--	100 | 19
LUMU2	GL	100 | 2	80 | 2	--	50 | 3	50 | 1	50 | 1	--	67 | 1
LUPA4	GL	--	--	--	--	--	50 | 1	--	--
LUSP4	GL	--	20 | 3	100 | 1	--	--	--	--	--

Appendix 8-5: Constancy and average cover of all species present in the following ecological types:

ARTRR/EL Big = ARTRR4/ELSP3, Bigsheep Family ET
ARTRR/FE Ledge = ARTRR4/FEID, Ledgefork Family ET
ARTRV/EL Win = ARTRV2/ELSP3, Winspect Family ET
ARTRV/FE Corbly 166D = ARTRV2/FEID, Corbly 166D Family ET
ARTRV/FE Kiev = ARTRV2/FEID, Kiev Family ET
ARTRV/FE Ledgefork = ARTV2/FEID, Ledgefork Family ET
ARTRV/FE Lithic Argi = ARTRV2/FEID, Lithic Argiustolls Family ET
ARTRV/FE Corbly 351L = ARTRV2/FEID, Corbly 351L Family ET
ARTRV/FE Shawmut = ARTRV2/FEID, Shawmut Family ET
ELSP3 Wabek = ELSP3, Wabek Family ET
ELSP3-PO Paunsaugunt = ELSP3-POSE-STENO7 Scabland, Paunsangunt Family ET
FE-EL Elwood = FEID-ELSP3-ACNE9, Elwood Family ET
FEID Ledgefork = FEID, Ledgefork Family ET

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	LF	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
PIAL	DO	--	--	--	--	--	--	--	--	--	--	--	50 | 5	--
PIFL2	DO	17 | 1	--	30 | 3	25 | 1	50 | 3	--	--	--	--	--	--	--	--
PIAL	SEED	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
PICOL	SEED	--	--	--	25 | 1	--	--	--	--	--	--	--	50 | 1	--
PIFL2	SEED	--	--	10 | 1	--	--	--	33 | 1	--	--	--	--	--	--
AMAL2	S	--	--	10 | 1	--	--	--	--	--	50 | 1	--	--	50 | 3	--
ARAR8	S	--	--	--	25 | 3	--	--	--	--	--	--	--	--	--
ARCA13	S	33 | 4	--	20 | 1	--	--	--	--	--	--	--	--	--	--
ARFR4	S	67 | 5	33 | 10	20 | 3	--	--	--	67 | 2	--	--	--	--	--	100 | 1
ARTRR4	S	100 | 20	100 | 8	60 | 3	--	--	--	--	--	75 | 2	--	33 | 1	--	--
ARTRV2	S	17 | 1	--	100 | 28	100 | 29	100 | 45	100 | 27	100 | 25	100 | 35	100 | 42	--	--	100 | 5	--
CEVE	S	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
CHVI8	S	50 | 1	--	60 | 2	50 | 1	50 | 1	--	100 | 1	--	75 | 1	--	--	--	--
JUCOD	S	--	--	--	--	--	--	--	100 | 1	--	--	--	100 | 2	--
JUOS	S	--	--	40 | 10	--	--	--	--	--	--	--	--	--	--
PRVIM	S	--	--	--	--	--	--	--	--	--	--	--	50 | 3	--
PUTR2	S	--	--	90 | 16	--	50 | 3	--	--	100 | 5	50 | 1	100 | 1	--	--	--
RHART2	S	--	--	--	--	--	--	--	--	--	100 | 3	--	--	--
RICEP	S	17 | 1	--	--	--	--	--	--	--	--	--	--	--	--
ROWO	S	17 | 1	--	50 | 2	--	--	--	--	--	--	--	--	50 | 1	--
SYORU	S	17 | 1	--	50 | 4	--	--	--	--	100 | 3	25 | 1	--	--	50 | 3	--
ACMIL3	F	17 | 1	--	10 | 1	--	100 | 1	--	--	--	75 | 2	--	33 | 3	--	--
AGGL	F	50 | 2	--	70 | 1	25 | 5	100 | 2	--	67 | 1	100 | 1	75 | 2	--	--	100 | 2	100 | 1
ALAL3	F	17 | 1	--	40 | 2	--	--	--	--	--	--	--	--	--	--
ALCE2	F	--	--	20 | 1	25 | 1	--	--	100 | 1	100 | 1	25 | 1	--	33 | 1	50 | 1	--
ALDE	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	**LF**	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
ALTE	F	--	--	10 | 1	25 | 3	--	--	--	--	--	--	--	--	--
ANAN2	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
ANCO	F	17 | 1	--	--	--	--	--	--	--	25 | 10	--	33 | 1	--	--
ANMA	F	17 | 1	--	--	--	--	--	--	--	--	--	33 | 1	--	--
ANMI3	F	17 | 1	--	--	25 | 3	--	--	--	--	--	--	--	--	--
ANRO2	F	17 | 1	33 | 3	30 | 2	25 | 1	50 | 1	--	33 | 3	--	--	--	--	--	--
ANSES	F	--	33 | 1	--	--	--	--	--	--	--	--	--	50 | 1	--
ANTEN	F	--	33 | 3	--	--	--	33 | 3	--	--	--	--	--	--	--
ANUM	F	17 | 1	33 | 1	10 | 1	50 | 1	50 | 1	67 | 1	67 | 1	100 | 3	75 | 2	--	33 | 1	100 | 4	100 | 5
ARFU3	F	--	--	10 | 1	--	--	--	33 | 1	--	--	--	33 | 1	--	--
ARHI	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
ARLU	F	--	--	40 | 2	--	--	--	--	--	--	100 | 3	--	--	--
ASAL7	F	--	--	10 | 10	--	--	--	--	--	--	--	--	--	--
ASAUG	F	--	--	40 | 2	--	--	--	--	--	--	--	--	--	--
ASMI9	F	67 | 2	67 | 1	40 | 2	100 | 3	100 | 3	67 | 4	100 | 2	--	100 | 5	--	100 | 2	100 | 1	100 | 3
ASTER	F	--	33 | 1	--	--	--	--	--	--	--	--	--	--	--
ASTRA	F	--	33 | 1	--	--	--	33 | 3	--	--	--	--	--	--	--
BAIN	F	67 | 1	--	50 | 4	50 | 2	50 | 1	--	100 | 1	100 | 1	50 | 9	--	67 | 2	--	--
BASA3	F	--	--	30 | 14	--	50 | 25	--	--	100 | 1	50 | 2	100 | 20	--	--	--
BEWY	F	--	--	--	--	--	--	--	--	25 | 1	--	67 | 1	--	--
BOAN6	F	--	--	--	--	50 | 1	--	--	--	--	--	--	--	--
BOECH	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
BOEX2	F	--	33 | 1	--	25 | 1	--	--	67 | 1	100 | 1	25 | 1	--	--	--	100 | 1
BOEHOL	F	--	33 | 1	--	25 | 1	--	--	--	--	75 | 1	--	--	--	--
BOLE5	F	33 | 1	--	--	--	--	--	--	--	--	--	--	--	--
BOMI3	F	17 | 1	--	--	--	100 | 1	--	--	--	--	--	33 | 1	--	--
BONU	F	--	33 | 1	--	--	--	--	--	--	--	--	--	--	--
BOPU5	F	--	--	--	25 | 1	--	33 | 1	--	--	--	--	--	--	--
BOWI	F	--	--	--	--	--	33 | 1	33 | 1	--	--	--	--	--	--
CAAN7	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
CACU7	F	17 | 1	--	--	--	--	--	--	--	--	--	--	--	--
CAFL7	F	--	--	--	--	--	--	67 | 1	--	--	--	--	--	--
CALI4	F	--	--	--	--	--	--	33 | 1	--	--	--	--	--	--
CAMI2	F	17 | 1	--	30 | 1	--	--	--	--	--	--	--	--	--	--
CANU3	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
CANU4	F	--	--	10 | 5	--	--	--	--	--	--	--	--	--	--

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	**LF**	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
CAPA25	F	33 | 1	--	--	75 | 1	--	33 | 1	33 | 1	100 | 1	50 | 2	--	67 | 1	--	--
CAPIL	F	--	--	10 | 1	25 | 1	--	33 | 1	--	--	--	--	--	--	--
CASTI2	F	17 | 1	--	10 | 1	--	50 | 1	33 | 1	--	--	25 | 1	--	33 | 1	--	--
CEAR4	F	--	--	--	--	50 | 1	--	--	--	50 | 3	--	--	--	--
CHDOM	F	33 | 2	--	--	25 | 1	--	--	--	--	--	--	--	--	--
CIRSI	F	17 | 1	--	--	--	--	--	--	--	--	--	--	--	--
COPA3	F	--	--	60 | 1	--	50 | 1	--	--	100 | 1	50 | 1	--	--	--	--
CRAC2	F	17 | 1	--	40 | 2	25 | 1	50 | 1	--	--	100 | 1	75 | 1	--	--	50 | 3	--
CRIN4	F	17 | 1	--	10 | 3	--	--	--	--	--	--	100 | 3	--	--	--
CRMO4	F	33 | 1	33 | 1	--	25 | 2	--	33 | 1	100 | 2	--	--	--	--	--	--
CYLO10	F	--	--	--	--	--	--	33 | 1	100 | 1	--	--	--	--	--
CYTEA	F	67 | 3	--	40 | 6	--	--	--	--	--	50 | 3	--	--	50 | 3	--
DENU2	F	--	--	10 | 1	--	50 | 1	--	--	100 | 1	--	--	--	--	--
DOCO	F	33 | 1	--	20 | 1	25 | 1	50 | 1	33 | 1	67 | 1	100 | 1	50 | 1	--	67 | 1	--	--
DODEC	F	--	33 | 1	--	--	--	--	--	--	25 | 1	--	--	--	--
DOPU	F	--	33 | 1	--	--	--	--	--	--	--	--	--	--	--
DRDE	F	--	--	--	--	--	--	33 | 1	--	--	--	--	--	--
DRAL4	F	--	--	10 | 1	--	--	--	--	100 | 1	--	--	--	--	--
DROL	F	33 | 1	--	--	--	--	--	--	--	--	--	33 | 3	--	--
ERAS2	F	67 | 1	--	40 | 1	--	50 | 1	--	--	--	--	--	--	--	--
ERCA2	F	17 | 1	67 | 1	10 | 1	25 | 1	--	--	67 | 1	--	--	--	67 | 1	--	--
ERCO24	F	33 | 3	67 | 1	20 | 1	25 | 1	--	67 | 1	33 | 1	100 | 1	75 | 1	--	67 | 1	100 | 2	100 | 1
ERCO5	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
ERCOD	F	67 | 2	67 | 1	40 | 1	25 | 1	50 | 1	67 | 1	67 | 1	100 | 1	50 | 1	--	67 | 1	100 | 1	--
EREA	F	--	--	--	25 | 3	--	--	--	--	--	--	--	--	--
ERLA	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
EROC	F	--	--	--	50 | 1	--	67 | 2	33 | 3	--	--	--	--	--	--
EROV	F	33 | 1	67 | 1	10 | 1	50 | 1	50 | 3	67 | 1	100 | 1	--	25 | 1	--	33 | 1	--	100 | 1
ERPU9	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
ERRY	F	67 | 1	--	--	--	--	--	--	--	--	--	33 | 1	--	--
ERSI3	F	33 | 2	--	--	--	--	--	--	--	--	--	--	--	--
ERTW	F	17 | 1	--	--	--	--	--	--	--	--	--	33 | 1	--	--
ERUM	F	33 | 1	--	50 | 2	75 | 2	100 | 1	33 | 3	--	100 | 3	100 | 2	--	--	100 | 4	--
FRAT	F	--	--	20 | 1	--	100 | 1	--	--	--	--	--	--	--	--
GAAR	F	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
GARA2	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	**LF**	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
GETR	F	--	33 | 1	--	50 | 1	--	67 | 1	33 | 1	100 | 1	25 | 1	--	--	100 | 1	--
GYPA2	F	--	--	--	--	--	33 | 1	--	--	--	--	--	--	--
IPSP	F	17 | 1	--	10 | 1	--	50 | 1	--	33 | 1	--	25 | 3	--	--	--	--
IVGO	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
LEFR4	F	50 | 1	--	20 | 1	--	--	--	--	--	25 | 1	--	33 | 1	--	--
LEPY2	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 1
LERE7	F	--	67 | 1	--	75 | 1	--	67 | 1	100 | 1	100 | 1	50 | 1	--	--	100 | 1	--
LIGLR	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
LILE3	F	67 | 1	--	50 | 1	--	--	--	--	--	--	--	33 | 1	--	--
LIRU4	F	--	--	50 | 1	--	--	--	--	--	25 | 1	100 | 5	--	--	--
LOCO4	F	17 | 1	--	--	--	--	--	--	--	25 | 1	--	67 | 6	--	--
LODIM	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
LOMAT	F	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
LOOR	F	67 | 1	33 | 1	70 | 1	75 | 2	100 | 2	67 | 1	67 | 1	--	75 | 1	--	33 | 1	--	--
LOTR2	F	--	--	--	--	50 | 1	--	--	100 | 1	--	--	--	--	--
LUAR3	F	17 | 1	--	--	--	--	--	--	--	25 | 3	--	--	--	--
LUPIN	F	17 | 1	--	--	--	100 | 1	--	--	--	--	--	--	--	--
LUPO2	F	17 | 1	--	20 | 3	--	--	--	--	--	75 | 2	--	--	50 | 1	--
MERTE	F	--	--	--	--	--	33 | 1	--	--	--	--	--	--	--
MEVI4	F	67 | 1	67 | 1	60 | 2	100 | 2	100 | 2	33 | 1	100 | 1	--	75 | 1	--	100 | 2	100 | 1	--
MIMA3	F	--	--	--	--	--	--	33 | 1	--	--	--	--	--	--
MINU4	F	17 | 1	--	20 | 1	--	50 | 1	--	33 | 1	--	--	--	--	--	--
MIOB2	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 5
MONU	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
MUMO	F	--	--	--	--	--	--	--	--	25 | 5	--	--	--	--
ORFA	F	--	--	--	25 | 1	--	--	--	--	--	--	--	--	--
OXSE	F	100 | 5	--	--	25 | 1	100 | 1	--	67 | 2	--	--	--	67 | 1	--	--
PACA15	F	83 | 1	--	60 | 1	--	--	--	33 | 1	100 | 1	--	--	--	50 | 1	--
PEHU	F	50 | 2	--	40 | 1	25 | 1	--	--	33| 1	100 | 1	--	--	33 | 1	--	--
PEPR2	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
PERA2	F	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
PERY	F	--	--	--	--	--	--	--	--	25 | 3	--	--	--	--
PHHO	F	83 | 3	67 | 2	90 | 2	75 | 3	100 | 1	67 | 3	100 | 2	--	50 | 3	--	67 | 2	--	100 | 1
PHLO2	F	--	--	--	--	--	33 | 1	--	--	--	--	--	--	--
PHMU3	F	83 | 3	67 | 4	40 | 2	75 | 2	100 | 6	33 | 1	67 | 2	100 | 3	100 | 2	--	100 | 2	100 | 3	--
PHMU4	F	--	--	20 | 1	--	--	--	--	--	--	--	--	--	--

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	**LF**	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
PHPU12	F	17 | 3	--	--	--	--	--	--	--	--	--	--	--	--
PHPU5	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 1
PHSE	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
POBI6	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
POBI10	F	--	--	--	--	--	--	33 | 1	--	--	--	--	--	--
POBR5	F	--	--	--	--	--	--	33 | 3	--	--	--	--	--	--
POCO13	F	17 | 1	33 | 1	--	--	--	--	--	--	--	--	--	--	100 | 1
POGL9	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
POGR9	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
POHI6	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 1
POOV2	F	--	--	--	25 | 1	--	--	--	--	--	--	33 | 1	--	--
POTEN	F	--	--	--	--	--	--	--	--	--	--	33 | 1	--	--
PYUN2	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 1
RAGLE	F	--	--	--	--	--	--	--	--	25 | 1	--	--	--	--
SARH2	F	--	33 | 1	10 | 1	--	--	--	--	--	--	--	67 | 2	--	--
SEIN2	F	--	--	20 | 2	--	100 | 1	--	--	100 | 1	25 | 3	--	--	--	--
SEIN4	F	--	--	30 | 2	--	--	--	--	100 | 1	50 | 2	--	--	--	--
SELA	F	50 | 1	100 | 2	30 | 1	100 | 2	50 | 1	67 | 2	67 | 2	100 | 1	--	--	100 | 2	50 | 1	100 | 3
SERA	F	17 | 2	--	--	--	--	--	--	--	--	--	--	--	--
SPRU	F	--	--	10 | 1	--	--	--	--	--	--	--	--	--	--
STAC	F	33 | 2	--	30 | 3	25 | 1	--	--	67 | 2	--	--	--	67 | 18	--	--
STST5	F	33 | 6	--	--	--	--	--	--	--	--	--	33 | 25	--	--
TAER2	F	50 | 2	--	--	--	--	--	--	--	25 | 1	--	--	--	--
TAOF	F	17 | 1	--	40 | 1	--	50 | 1	--	--	--	75 | 2	--	--	--	--
TRAGO	F	17 | 1	--	--	--	--	--	--	--	--	--	--	--	--
TRDU	F	--	--	20 | 1	--	--	--	--	--	25 | 1	--	--	--	--
TRLA30	F	--	--	--	--	--	--	--	--	--	--	--	50 | 1	--
TRNA2	F	--	--	--	--	--	--	--	--	--	--	--	--	100 | 3
VIOLA	F	--	--	30 | 1	--	--	--	--	--	--	--	--	--	--
ZIEL2	F	--	--	--	--	--	--	--	--	25 | 3	--	--	--	--
ZIVEG	F	50 | 1	--	30 | 1	--	--	--	--	--	25 | 1	--	33 | 1	--	--
ACNE9	G	--	--	--	--	--	--	33 | 1	100 | 1	--	--	--	100 | 1	--
BRTE	G	17 | 1	--	50 | 14	25 | 1	--	--	--	--	--	100 | 40	--	--	--
ELEL5	G	--	--	--	75 | 2	--	33 | 1	--	--	25 | 1	--	--	50 | 1	100 | 1
ELSP3	G	100 | 19	67 | 4	100 | 10	75 | 5	100 | 8	--	100 | 5	100 | 1	100 | 4	100 | 15	100 | 11	50 | 3	--
FEID	G	--	100 | 9	20 | 1	100 | 15	100 | 18	100 | 13	100 | 8	100 | 20	100 | 20	100 | 3	--	100 | 12	100 | 10

Ecological Type		ARTRR/ EL Big	ARTRR/ FE Ledge	ARTRV/ EL Win	ARTRV/FE Corbly 166D	ARTRV/FE Kiev	ARTRV/FE Ledgefork	ARTRV/FE Lithic Argi	ARTRV/FE Corbly 351L	ARTRV/FE Shawmut	ELSP3 Wabek	ELSP3-PO Paunsaugunt	FE-EL Elwood	FEID Ledgefork
Species	**LF**	n=6	n=3	n=10	n=4	n=2	n=3	n=3	n=1	n=4	n=1	n=3	n=2	n=1
HECO26	G	--	--	--	24 ǀ 1	--	--	--	--	--	100 ǀ 1	--	--	--
KOMA	G	33 ǀ 10	--	60 ǀ 4	--	--	--	--	--	50 ǀ 3	100 ǀ 3	100 ǀ 9	--	100 ǀ 3
LEKI2	G	67 ǀ 3	--	70 ǀ 3	25 ǀ 3	100 ǀ 3	--	--	100 ǀ 1	50 ǀ 2	--	--	100 ǀ 3	--
PIMI7	G	--	--	--	--	--	--	--	--	--	--	--	50 ǀ 5	--
POFE	G	--	--	10 ǀ 5	25 ǀ 3	--	33 ǀ 1	--	--	--	--	--	--	--
POJU	G	--	--	--	25 ǀ 1	--	--	--	--	--	--	--	--	--
POPA3	G				--			33 ǀ 3						
POPR	G	--	--	10 ǀ 1	--	--	--	--	--	25 ǀ 3	--	--	--	--
POSE	G	100 ǀ 21	67 ǀ 12	90 ǀ 16	100 ǀ 10	100 ǀ 22	67 ǀ 20	100 ǀ 22	100 ǀ 15	100 ǀ 11	100 ǀ 1	100 ǀ 17	100 ǀ 3	100 ǀ 25
POWH2	G	--	--	--	--	--	--	--	--	--	--	--	100 ǀ 2	--
CABRP3	GL	17 ǀ 1	--	--	--	--	33 ǀ 1	--	--	--	--	--	--	100 ǀ 1
CACA13	GL	--	--	--	29 ǀ 1	--	--	67 ǀ 1	--	--	--	--	--	--
CAFOV	GL	--	33 ǀ 1	--	--	--	--	--	--	--	--	--	--	--
CANA2	GL	--	--	--	--	--	--	33 ǀ 1	--	50 ǀ 1	--	67 ǀ 6	--	--
CAOR	GL	--	--	--	--	--	--	--	--	25 ǀ 1	--	--	--	--
CAREX	GL	--	--	--	50 ǀ 1	--	--	--	--	50 ǀ 1	--	--	--	--
CARO5	GL	--	--	40 ǀ 5	--	50 ǀ 5	--	--	100 ǀ 1	--	--	--	50 ǀ 1	--
CAST40	GL	--	33 ǀ 1	10 ǀ 1	25 ǀ 3	--	--	--	--	--	--	--	--	--
CAVA3	GL	--	--	--	--	--	--	--	--	--	100 ǀ 1	--	--	--
CAXE	GL	--	--	--	--	--	--	--	--	25 ǀ 3	--	--	--	--

Appendix 8-6: Constancy and average cover of all species present in the following ecological types:

DECE Elvick = Elvick, Oxyaquic Eutrocryepts - DECE Habitat Type
POTR5/COSE16 Mantador = POTR5/COSE16-ALVIS, Mantador Family ET
POTR5/COSE16 Caryville = POTR5/COSE16-ALVIS, Caryville Family ET
POTR5/GEVI2 Bullflat = POTR5/GEVI2, Bullflat Family ET
POTR5/SYORU Boulder = POTR5/SYORU-Boulder, Ledgefork Family ET
SAPL2/CASC12 Elvick = Elvick, Oxyaquic Eutrocryepts
SALIX/CAREX Moose River = SALIX/CAREX, Moose River Family ET - SAPL2/CASC12 Community Type
SALIX CAREX Kettle = SALIX/CAREX – Kettle Lake, Fluvaquentic Cryaquepts ET

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU- Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
PICOL	DO	--	--	--	12 | 3	25 | 20	--	--	--
PIEN	DO	--	--	--	--	--	--	50 | 1	--
POTR5	DO	--	100 | 10	100 | 5	100 | 34	75 | 18	--	--	--
PSMEG	DO	--	--	--	12 | 5	--	--	--	--
ABLA	SD	--	--	100 | 5	--	25 | 1	--	--	--
JUSC2	SD	--	--	--	12 | 20	--	--	--	--
PICOL	SD	--	--	100 | 10	12 | 1	25 | 10	--	--	--
POTR5	SD	--	--	--	38 | 9	50 | 6	--	--	--
PSMEG	SD	--	--	--	12 | 1	--	--	--	--
ABLA	U	--	--	100 | 3	--	25 | 1	--	50 | 1	--
JUSC2	U	--	--	--	12 | 1	--	--	--	--
PICOL	U	--	--	100 | 1	25 | 2	75 | 2	--	--	--
PIEN	U	--	--	--	--	--	--	50 | 1	--
PIFL2	U	--	--	--	38 | 4	25 | 1	--	--	--
POTR5	U	--	--	100 | 25	88 | 8	100 | 19	--	--	--
PSMEG	U	--	--	--	38 | 3	--	--	--	--
ABLA	SEED	--	--	--	--	--	--	100 | 3	--
PIAL	SEED	--	--	--	--	25 | 3	--	--	--
PICOL	SEED	--	--	100 | 1	25 | 1	75 | 3	--	--	--
PIEN	SEED	--	--	--	--	--	--	100 | 1	--
PIFL2	SEED	--	--	--	50 | 2	25 | 1	--	--	--
POTR5	SEED	--	--	100 | 3	88 | 8	100 | 7	--	--	--
PSMEG	SEED	--	--	--	25 | 3	--	--	--	--
ACGL	S	--	--	100 | 10	12 | 1	--	--	--	--
ALVIS2	S	--	100 | 3	--	12 | 3	--	--	--	--
AMAL2	S	--	--	100 | 5	25 | 2	25 | 3	--	--	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
ARTRV2	S	--	--	--	--	25 | 1	--	--	--
ARUV	S	--	--	100 | 1	--	25 | 3	--	--	--
CEVE	S	--	--	--	--	50 | 3	--	--	--
COSE16	S	--	--	100 | 10	--	--	--	--	--
JUCOD	S	--	--	100 | 5	75 | 2	75 | 5	--	--	--
KAMI	S	--	--	--	--	--	--	50 | 1	--
LOIN5	S	--	--	100 | 5	12 | 1	--	--	--	--
MARE11	S	--	--	100 | 3	75 | 2	100 | 3	--	--	--
PAMY	S	--	--	--	38 | 7	--	--	--	--
PEFL15	S	--	--	--	25 | 2	--	--	--	--
PRVIM	S	--	100 | 1	100 | 5	62 | 2	25 | 1	--	--	--
PUTR2	S	--	--	--	12 | 1	25 | 1	--	--	--
RIHU	S	--	100 | 3	--	--	--	--	--	--
RILA	S	--	--	100 | 5	--	--	--	--	--
RIOX	S	--	--	--	12 | 1	--	--	--	--
ROWO	S	--	--	100 | 5	100 | 2	75 | 2	--	--	--
RUID	S	--	--	--	--	25 | 1	--	--	--
SACA6	S	--	--	--	--	--	100 | 25	--	--
SAER	S	--	--	100 | 10	--	--	--	--	--
SAGLV	S	--	--	--	--	--	--	50 | 10	--
SAMBU	S	--	--	--	--	25 | 1	--	--	--
SAGE2	S	--	--	--	--	--	--	--	100 | 15
SAPL2	S	--	--	--	--	--	100 | 15	100 | 75	100 | 25
SAWO	S	--	--	--	--	--	--	--	100 | 35
SASC	S	--	--	--	12 | 1	--	--	--	--
SHCA	S	--	--	--	75 | 10	25 | 5	--	--	--
SYORU	S	--	--	--	38 | 1	100 | 3	--	--	--
VAOC	S	--	--	--	--	--	100 | 3	--	--
VASC	S	--	--	100 | 5	--	25 | 10	--	--	--
ACCO4	F	--	--	--	12 | 1	--	--	--	--
ACMIL3	F	100 | 1	--	--	88 | 2	50 | 1	--	50 | 1	100 | 3
ACRU2	F	--	100 | 1	100 | 1	25 | 2	--	--	--	--
AGGL	F	100 | 3	--	--	50 | 1	25 | 1	--	--	--
ALSC	F	--	--	--	12 | 1	--	--	--	--
ANME2	F	--	--	--	--	--	100 | 1	50 | 1	--
ANRO2	F	--	--	100 | 1	12 | 1	50 | 2	--	--	--
ANTEN	F	--	--	--	12 | 1	50 | 1	--	--	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
ANUM	F	100 | 3	--	100 | 1	--	--	--	--	100 | 1
APAN2	F	--	--	100 | 3	--	50 | 2	--	--	--
AQCO	F	--	--	--	62 | 1	--	--	--	--
ARCO9	F	--	--	100 | 3	88 | 5	100 | 5	--	--	--
ARMO4	F	100 | 10	--	--	--	--	--	--	--
ARSC	F	--	--	--	--	--	100 | 5	--	--
ASAG2	F	--	--	--	25 | 2	--	--	--	--
ASAUG	F	--	--	--	50 | 4	--	--	--	--
ASMI9	F	--	--	--	12 | 5	--	--	--	--
BAIN	F	--	--	--	12 | 1	--	--	--	--
BASA3	F	--	--	--	38 | 2	50 | 1	--	--	--
BOAN6	F	--	--	--	--	25 | 1	--	--	--
BOECH	F	--	--	--	--	25 | 3	--	--	--
BOEHOL	F	--	--	100 | 1	--	25 | 1	--	--	--
CAEU	F	--	--	--	12 | 1	--	--	--	--
CALE4	F	--	--	--	--	--	100 | 1	100 | 6	--
CALI4	F	--	--	--	50 | 2	50 | 1	--	--	--
CAMI12	F	--	--	100 | 1	--	--	--	--	--
CARH4	F	--	--	--	12 | 3	--	--	--	--
CARO2	F	--	--	100 | 1	38 | 2	25 | 1	--	--	--
CASTI2	F	--	--	--	--	25 | 1	--	--	--
CEAR4	F	100 | 1	--	--	12 | 1	--	--	--	--
CHAN9	F	--	100 | 5	100 | 5	50 | 1	75 | 2	--	--	--
COLI2	F	--	--	--	12 | 1	--	--	--	--
COPA3	F	--	--	--	12 | 1	50 | 1	--	--	--
COTR3	F	--	--	--	38 | 1	--	--	--	--
COWI2	F	--	--	--	12 | 1	--	--	--	--
CRAC2	F	--	--	--	--	25 | 1	--	--	--
CRRU3	F	--	--	--	12 | 1	--	--	--	--
DEIN5	F	--	100 | 3	--	--	--	--	--	--
DEOC	F	--	--	--	25 | 1	--	--	--	--
DENU2	F	--	--	--	25 | 1	--	--	--	--
DIUN	F	--	--	--	12 | 3	--	--	--	--
DOPU	F	--	--	--	--	--	100 | 1	--	--
ELRU	F	100 | 1	--	--	--	--	--	--	--
EPCI	F	--	--	--	12 | 1	--	--	--	--
EPGLF2	F	--	100 | 1	--	--	--	--	--	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
EPHA	F	100 | 1	--	--	--	--	--	--	--
EPPA	F	--	--	--	12 | 1	--	--	--	--
EPPY4	F	--	--	100 | 1	--	--	--	--	--
ERCO24	F	--	--	--	12 | 3	--	--	--	--
ERPES3	F	--	--	--	--	--	100 | 1	50 | 3	--
ERSI3	F	--	--	--	--	--	100 | 1	--	--
ERUM	F	--	--	--	12 | 1	25 | 1	--	--	--
ERUR2	F	--	--	--	--	--	--	--	100 | 1
EUGL13	F	--	--	--	--	25 | 1	--	--	--
FRSP	F	--	--	--	38 | 2	--	--	--	--
FRVI	F	--	--	--	88 | 1	25 | 1	--	--	100 | 1
GABO2	F	--	--	100 | 3	100 | 5	25 | 1	--	--	--
GEMA4	F	--	--	--	12 | 1	--	--	--	100 | 1
GERI	F	--	100 | 3	100 | 3	12 | 1	25 | 3	--	50 | 3	--
GEROT	F	--	--	--	--	--	100 | 5	--	--
GETR	F	100 | 1	--	--	12 | 1	--	--	--	--
GEVI2	F	--	--	--	75 | 2	--	--	--	--
HEQU2	F	--	--	--	75 | 5	--	--	--	--
HESPL	F	--	100 | 3	--	--	--	--	--	--
HIAL2	F	--	--	100 | 1	12 | 1	--	--	--	--
LIRU4	F	--	--	--	12 | 1	--	--	--	--
LOMAT	F	--	--	--	12 | 1	--	--	--	--
LOTR2	F	--	--	--	38 | 2	25 | 1	--	--	--
LUAR3	F	--	--	--	38 | 1	--	--	--	--
LUPO2	F	--	--	--	38 | 4	--	--	--	--
MAST4	F	--	100 | 1	--	38 | 1	--	--	--	--
MEVI4	F	--	--	--	12 | 1	--	--	--	--
MIAU3	F	--	--	--	--	--	100 | 1	--	--
MIGLJ	F	--	100 | 3	--	--	--	--	--	--
ORAL4	F	--	--	--	--	--	100 | 1	--	--
ORSE	F	--	--	100 | 1	12 | 3	--	--	--	--
OSBE	F	--	--	--	12 | 5	--	--	--	--
OSDE	F	--	--	100 | 3	50 | 5	--	--	--	--
OSPU	F	--	--	--	25 | 2	--	--	--	--
PAST10	F	--	--	--	--	25 | 1	--	--	--
PASU40	F	--	--	--	--	--	--	50 | 1	--
PEGR2	F	--	--	--	12 | 1	--	100 | 5	50 | 1	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
PERY	F	--	--	--	12 | 1	--	--	--	--
PEST2	F	--	--	100 | 1	--	25 | 1	--	--	--
PHSE	F	--	--	--	12 | 1	--	--	--	--
PLSCH	F	100 | 1	--	--	--	--	--	--	--
POAR7	F	--	--	--	12 | 1	25 | 1	--	--	--
POBI6	F	100 | 1	--	--	38 | 1	--	100 | 1	50 | 3	--
PODI2	F	100 | 10	--	--	25 | 1	--	--	100 | 3	100 | 3
PODO4	F	--	--	100 | 1	12 | 1	--	--	--	--
POGL9	F	--	--	--	12 | 1	--	--	--	--
POGR9	F	--	--	--	62 | 1	--	100 | 5	--	--
POVI3	F	--	--	--	--	--	100 | 3	--	--
PRTR4	F	--	--	--	12 | 1	--	--	--	--
PYAS	F	--	--	100 | 5	25 | 1	--	--	--	--
RAUN	F	--	--	--	12 | 1	--	--	--	--
RUAQF	F	100 | 1	--	--	--	--	--	--	--
SARH2	F	--	--	--	--	--	100 | 1	--	--
SECR	F	--	--	--	--	--	--	50 | 1	--
SEHY	F	--	--	--	--	--	--	50 | 1	--
SEHY2	F	--	--	--	--	--	--	100 | 6	--
SEIN2	F	100 | 1	--	--	25 | 1	25 | 1	--	--	--
SEIN4	F	--	--	--	25 | 1	--	100 | 1	--	--
SERH	F	--	--	--	--	--	--	50 | 5	--
SERO2	F	--	--	--	--	--	--	50 | 1	--
SETR	F	--	--	--	--	--	--	50 | 1	--
SIDR	F	--	--	--	--	25 | 1	--	--	--
SOCA6	F	--	--	--	25 | 2	--	--	--	--
SOMUS	F	--	--	100 | 5	--	--	--	--	--
SOVE6	F	--	--	--	--	25 | 3	--	--	--
STAM2	F	--	--	100 | 1	--	--	--	--	--
STLO2	F	--	--	--	--	--	--	--	100 | 1
SYFO2	F	--	--	--	38 | 4	25 | 3	--	50 | 1	--
SYSP	F	100 | 1	100 | 5	--	12 | 1	--	--	--	--
TAER2	F	--	--	--	12 | 1	--	--	--	--
TAOF	F	100 | 1	100 | 1	--	75 | 2	25 | 1	--	--	--
THALI2	F	--	--	--	12 | 1	--	--	--	--
THFE	F	--	--	--	25 | 3	--	--	--	--
THOC	F	--	--	--	50 | 2	--	--	--	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
THSPS	F	--	--	100 ǀ 3	--	--	--	--	--
THVE	F	--	--	--	12 ǀ 10	--	--	--	--
TRAL8	F	--	--	--	--	--	--	50 ǀ 10	--
VEAN2	F	--	--	--	--	--	--	50 ǀ 3	--
VEWO2	F	--	--	--	--	--	100 ǀ 3	50 ǀ 3	--
VIOLA	F	--	--	100 ǀ 1	50 ǀ 1	25 ǀ 1	--	--	--
ZIEL2	F	--	--	--	12 ǀ 1	--	--	--	--
ZIVEG	F	--	--	--	12 ǀ 1	--	--	--	--
EQAR	FH	--	--	--	25 ǀ 2	--	--	--	--
EQHYA	FH	--	--	--	12 ǀ 1	--	--	--	--
EQVA	FH	--	--	100 ǀ 3	--	--	--	--	--
ACNE9	G	--	--	100 ǀ 1	25 ǀ 1	25 ǀ 1	--	--	--
AGHU	G	--	--	--	--	--	--	50 ǀ 1	--
AGSC5	G	100 ǀ 1	--	--	--	--	--	--	--
AGVA	G	--	--	--	--	--	100 ǀ 1	--	--
BRCI2	G	--	--	--	25 ǀ 3	--	--	--	--
BRIN2	G	--	--	--	25 ǀ 2	25 ǀ 1	--	--	--
BRPU6	G	--	--	--	--	25 ǀ 5	--	--	--
BRVU	G	--	100 ǀ 3	--	--	--	--	--	--
CACA4	G	--	--	100 ǀ 5	--	--	--	50 ǀ 15	100 ǀ 3
CAIN	G	--	--	--	12 ǀ 1	--	--	--	--
CASC	G	--	--	--	12 ǀ 10	--	--	--	--
CAST36	G	100 ǀ 1	--	--	--	--	--	--	--
DAIN	G	100 ǀ 3	--	--	12 ǀ 1	--	--	--	--
DASP2	G	--	--	--	--	--	--	50 ǀ 1	--
DEAT2	G	--	--	--	--	--	--	50 ǀ 5	--
DECE	G	100 ǀ 45	--	--	12 ǀ 1	--	100 ǀ 15	50 ǀ 1	100 ǀ 1
DEEL	G	--	--	--	--	--	100 ǀ 1	--	--
ELEL5	G	--	--	--	--	75 ǀ 2	--	--	--
ELGL	G	--	100 ǀ 1	100 ǀ 5	12 ǀ 5	25 ǀ 3	--	--	--
ELLA3	G	--	--	--	--	25 ǀ 3	--	--	--
ELRE4	G	--	--	--	12 ǀ 3	--	--	--	--
ELSM3	G	--	--	--	12 ǀ 5	--	--	--	--
ELSP3	G	--	--	--	12 ǀ 1	--	--	--	--
ELTR7	G	100 ǀ 3	--	--	38 ǀ 3	--	--	--	--
FEAR3	G	--	--	--	12 ǀ 1	--	--	--	--
FEID	G	--	--	--	12 ǀ 1	--	--	--	--

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU-Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
FESA	G	--	--	--	--	--	100 | 1	--	--
GLGR	G	--	100 | 1	--	--	--	--	--	--
KOMA	G	100 | 1	--	--	--	--	--	--	--
LEKI2	G	--	--	100 | 1	12 | 1	50 | 1	--	--	--
MEBU	G	--	--	--	12 | 10	--	--	--	--
PHAL2	G	100 | 5	--	--	12 | 1	--	100 | 3	100 | 1	--
PIEX3	G	--	--	--	12 | 1	50 | 1	--	--	--
PIMI7	G	--	--	100 | 1	--	25 | 3	--	--	--
POAR21	G	--	--	--	12 | 1	--	--	--	--
POAR3	G	--	--	--	12 | 1	25 | 1	--	--	--
POCU3	G	--	--	--	12 | 1	--	--	50 | 1	--
POFE	G	--	--	--	25 | 3	75 | 6	--	--	--
POJU	G	100 | 3	--	--	25 | 4	--	--	--	--
POPR	G	100 | 3	--	--	75 | 6	--	--	--	--
PORE	G	--	--	--	--	--	--	50 | 7	--
POSE	G	100 | 1	--	100 | 3	12 | 1	25 | 1	--	--	--
POTR2	G	--	100 | 1	--	12 | 1	--	--	--	--
POWH2	G	--	--	100 | 1	25 | 3	50 | 2	--	--	--
PUCU	G	--	--	--	12 | 1	--	--	--	--
TRSP2	G	--	--	--	50 | 1	--	--	--	--
CAAQ	GL	100 | 1	--	--	--	--	--	--	--
CACA13	GL	--	--	--	--	--	100 | 3	--	--
CAGE2	GL	--	--	--	25 | 4	--	--	--	--
CAHA6	GL	100 | 3	--	--	--	--	--	--	--
CAHO5	GL	--	--	--	38 | 1	25 | 3	--	--	--
CALEP4	GL	--	--	--	--	--	--	--	100 | 3
CAMA9	GL	--	--	--	--	--	100 | 1	--	--
CAMI7	GL	100 | 15	--	--	--	--	--	--	--
CANI2	GL	--	--	--	--	--	--	100 | 6	--
CAPE42	GL	100 | 1	--	--	--	--	--	--	--
CAPR7	GL	--	--	--	12 | 1	--	--	--	100 | 3
CAREX	GL	--	--	--	--	25 | 1	--	--	--
CARO5	GL	--	100 | 1	--	--	75 | 4	--	--	--
CASA10	GL	--	--	100 | 3	--	--	--	--	--
CASC12	GL	100 | 3	--	--	--	--	100 | 5	100 | 15	--
CAVA3	GL	--	--	--	12 | 1	--	--	--	--
CAVE6	GL	--	--	--	--	--	--	--	100 | 65

Ecological Type		DECE Elvick	POTR5/COSE16 Mantador	POTR5/COSE16 Caryville	POTR5/GEVI2 Bullflat	POTR5/SYORU- Boulder	SAPL2/CASC12 Elvick	SALIX/CAREX Moose River	SALIX/CAREX Kettle
Species	**LF**	n=1	n=1	n=1	n=8	n=4	n=1	n=2	n = 1
									--
CAVU2	GL	--	--	--	12 | 1	--	--	--	--
CAXE	GL	--	--	--	12 | 5	--	--	--	--
ELQU2	GL	--	--	--	--	--	100 | 10	--	--
JUBA	GL	--	--	--	25 | 1	--	--	--	--
JUHA	GL	100 | 10	--	--	12 | 1	--	--	50 | 1	--
JUTR4	GL	--	--	--	--	--	--	50 | 1	--
LUPA4	GL	--	--	--	--	--	--	50 | 1	--

Appendix 9: List of Animal and Fish and Pest and Disease Species

List of animal and fish (Table 9-1) and pest and disease (Table 9-2) species discussed in body of text.

Table 9-1. List of animal and fish species.

Common name	Scientific name
American robin	*Turdus migratorius*
bat	Family: Chiroptera
beaver	*Castor canadensis*
black bear	*Ursus americanus*
black-capped chickadee	*Poecile atricapilla*
blue grouse	*Dendragapus obscurus*
brook trout	*Salvelinus fontinalis*
chickadee	*Poecile* spp.
chipmunk	*Eutamius* spp.
Clark's nutcracker	*Nucifraga columbiana*
cougar	*Felis concolor*
coyote	*Canis latrans*
crossbill	*Loxia* spp.
crow	*Corvus brachyrhynchos*
cutthroat trout	*Oncorhynchus clarki*
dark eyed junco	*Junco hyemalis*
deer mice	*Peromyscus maniculatus*
domestic cattle	*Bos taurus*
domestic goat	*Capra hircus*
domestic sheep	*Ovis aries*
elk	*Cervus elaphus*
flycatcher	*Empidonax* spp.
flying squirrel	*Glaucomys sabrinus*
fox	*Vulpes fulva*
golden trout	*Oncorhynchus aguabonita*
grizzly bear	*Ursus horribilis*
grouse	*Genus: Centrocerus, Perdix*
horned larks	*Eremophila alpestris*
horse	*Equus caballus*
juncos	*Junco* spp.
kinglet	*Regulus* spp.
lynx	*Lynx canadensis*
marmot	*Marmota flaviventris*
meadow vole	*Microtus pennsylvanicus*
moose	*Alces alces*
mountain chickadee	*Poecile gambeli*
mountain goats	*Oreamnos americanus*
mule deer	*Odocoileus hemionus*
muskrat	*Ondatra zibethicus*

Common name	Scientific name
northern goshawk	*Accipiter gentilis*
nuthatch	*Sitta* spp.
Ord's kangaroo rat	*Dipodomys ordi*
owl	*Familes: Strigidae, Tytonidae*
pika	*Ochotona princeps*
pine marten	*Martes americana*
pine siskin	*Carduelis pinus*
pocket gopher	*Thomomys talpoides*
porcupine	*Erethizon dorsatum*
pronghorn	*Antilocapra americana*
rainbow trout	*Oncorhynchus mykiss*
red crossbill	*Loxia curvirostra*
red squirrel	*Tamiasciurus hudsonicus*
red-breasted nuthatch	*Sitta canadensis*
Rocky Mountain bighorn sheep	*Ovis canadensis*
ruffed grouse	*Bonasa umbellus*
sage grouse	*Centrocerus urophasianus*
sagebrush voles	*Lagurus curtatus*
sandhill crane	*Grus canadensis*
shrew	Family: Soricidae
snowshoe hare	*Lepus americanus*
thrush	*Family: Turdidae*
voles	*Microtus* spp. and *Lagurus* spp.
western cottontail	*Sylvilagus nuttalli*
western harvest mice	*Reithrodontomys megalotis*
white-crowned sparrow	*Zonotrichia leucophrys*
whitetail jackrabbit	*Lepus townsendi*
white-tailed deer	*Odocoileus virginianus*
woodpecker	Family: Picidae

Table 9-2. List of pest and disease species.

Common name	Scientific name
annosus root disease	*Heterobasidion annosum*
black stem rust	*Puccinia tanaceti*
black-felt fungus	*Herpotrichia nigra*
blue stain fungi	*Ceratocystis* spp.
brown felt blight	*Neopeckia coulteri*
comandra blister rust	*Cronartium comandrae*
Douglas-fir beetle	*Dendroctonus pseudotsugae*
Douglas-fir cone moth	*Barbara colfaxiana*
dwarf mistletoe	*Arceuthobium* spp.
fir broom rust	*Melampsorella caryophyllacearum*
leaf rust fungi	*Melampsora* spp.
leaf spot and shoot blight	*Marssonina populi*
limber pine dwarf mistletoe	*Arceuthobium cyanocarpum*
lodgepole needle cast	*Lophodermella concolor*
lodgepole pine dwarf mistletoe	*Arceuthobium americanum*
longhorned beetles	Family: Cerambycidae
metallic wood borers	Family: Buprestidae
mormon cricket	*Anabrus simplex*
mountain pine beetle	*Dendroctonus ponderosae*
pine cone beetle	*Conophthorus ponderosae*
pine engraver beetles	*Ips* spp.
pine needle cast	*Lophodermella arcuata*
red belt fungus	*Fomitopsis pinicola*
red ring rot	*Phellinus pini*
schweinitzii root and butt rot	*Phaeolus schweinitzii*
snowmold fungus	*Ascomycete* spp.
stalactiform blister rust	*Cronartium coleosporioides*
sugar pine tortrix	*Choristoneura lambertiana*
tomentosus root disease	*Inonotus tomentosus*
western balsam bark beetle	*Dryocoetes confusus*
western conifer seed bug	*Leptoglossus occidentalis*
western spruce budworm	*Choristoneura occidentalis*
white pine blister rust	*Cronartium ribicola*

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