Coconino National Forest

Ecological Sustainability Report

United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

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The two panels above illustrate the extent of change in ponderosa pine forest. This photo comparison is from Walker Lake on the Coconino National Forest north of Flagstaff, Arizona. The top panel is from 1875 where the system is characterized by mid- and mature-aged trees with an open canopy, grass understory, and low risk of uncharacteristic fire. In contrast, the forest in 2003 shows a closed canopy and markedly higher density of trees, yielding heavy fuel loads and a much higher risk of uncharacteristic fire (Photographs courtesy of the Ecological Restoration Institute).

This Ecological Sustainability Report is technical in nature. It is based on a variety of specialist, agency and Regional reports, databases, models, and literature. Contributors include:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

This ecological sustainability report describes and evaluates the ecological environment of the Coconino National Forest (hereafter called the Coconino or Forest) and the surrounding area. The report assesses the diversity of ecosystems and species on the Forest, and identifies threats and associated risks to the long-term sustainability of these systems across a larger landscape.

This report is organized into five chapters followed by appendices. Chapter 1 describes the Forest and compares it to the surrounding landscape, providing the basis for Forest contributions at larger scales. The ecosystem diversity section (Chapter 2) describes current conditions and trends of vegetative communities and associated physical resources (soils, aquatic systems, and airsheds). It also includes a section on climate change for the southwestern United States. The species diversity section (Chapter 3) discusses various birds, mammals, amphibians, reptiles, invertebrates, fish, and plants that inhabit various communities on the Coconino. Risks to ecosystems and species on the Forest are discussed in Chapter 4 and the threats contributing to those risks are identified. Chapter 5 summarizes ecosystem characteristics at substantial risk and makes recommendations for ecosystem characteristics needing change. Appendices include a glossary, smoke management map, vegetation descriptions and maps, and soil condition data. Along with public input, these findings serve as baseline components for the Need for Change Report along with the Coconino Economic and Social Sustainability Assessment (USDA Forest Service 2008b). The Need for Change Report will recommend potential needs for change in the existing Forest Plan (Forest Land and Resource Management Plan, as amended) (USDA Forest Service 1987).

DESCRIPTION OF THE PLANNING UNIT

Coconino National Forest is located in north central Arizona. It is one of six National Forests in Arizona, occupying 1,842,699 acres in Coconino, Yavapai and Gila counties (Figure 1). The Forest borders the Kaibab, Prescott, Tonto and Apache-Sitgreaves national forests, private land, and lands administered by the State of Arizona, National Park Service, and the Navajo Nation.

The Forest ranges in elevation between 2,600 and 12,633 feet. The northern portion is pockmarked by numerous cinder hills and volcanoes, including the San Francisco Peaks which contains the highest point in Arizona. The Forest is bordered on the south by the Mogollon Rim, a 1,000-foot high cliff that runs for about 200 miles across central Arizona. It is dissected by deep canyons that contain several perennial streams and is flanked on the southwest by the Verde River.

Figure 1: Coconino National Forest in relationship to Arizona counties

Weather: Weather ranges from cold winters, mild summers and considerable diurnal temperature fluctuations at higher elevations, to mild winters and hot summers at lower elevations (Hereford 2007). Variability in weather patterns strongly influences the structure, composition, and function of Forest resources. In turn, weather is influenced by physiography, topographic relief, and proximity to major moisture sources. The average precipitation for the Forest is represented by weather data from Flagstaff, Arizona, which lies at 7,000 feet in the northern part of the Forest and Cottonwood, Arizona at 3,300 feet near the southern part of the Forest. Average annual rainfall is 21 inches in Flagstaff and 12 inches in Cottonwood. Average annual snowfall in Flagstaff is about 89 inches (Western Regional Climate Center 2009).

Past precipitation in the southwest and on the Forest has varied greatly. Climate history shows a period of unusually wet weather in the late 20th century between two dry intervals (1942-1978) and an ongoing early 21st century drought. There are distinct winter and summer peaks in precipitation. Summer rainfall tends to be more abundant, less variable and more reliable than winter and spring precipitation. Summer rainfall is generally preceded by a pre-monsoon drought, followed by an arid fall. Winter and spring moisture however are more hydrologically

meaningful because most of the summer rainfall is rapidly lost to evaporation and surface runoff (Sheppard et al. 1999). The timing and amount of water are critical determinants in the recruitment, establishment and maintenance of woody and herbaceous vegetation (Stromberg et al. 1991).

Vegetation: The Forest has a high diversity of vegetative communities due to the wide range of elevations, complex topography, and the presence of perennial water. Vegetative communities at the lowest elevations are more typical of Sonoran Deserts while the highest elevation community is the only well developed alpine tundra in Arizona. In between are extensive areas of piñon juniper, ponderosa pine, and mixed conifer forests interspersed with grasslands and scattered pockets of aspen at higher elevations. Riparian vegetation lines stream courses of perennial and intermittent water.

Watersheds: Watersheds are cataloged using a uniform hierarchical system developed by the United States Geological Survey. The United States is divided and sub-divided into successively smaller hydrologic units. The hydrologic units are nested within each other, from the largest to the smallest (region, sub-region, basin, and subbasin). This report focuses on subbasins (referred to as 4th code watersheds) and the next smaller watersheds within them (5th code watersheds). As shown in Figure 2, the Coconino NF extends across seven 4th code watersheds with water draining either into the Little Colorado River basin to the east or Verde River basin to the west. The 4th code watershed scale is the spatial extent used in this report to describe the ecological niche of the Forest with respect to aquatic ecosystems and water resources.

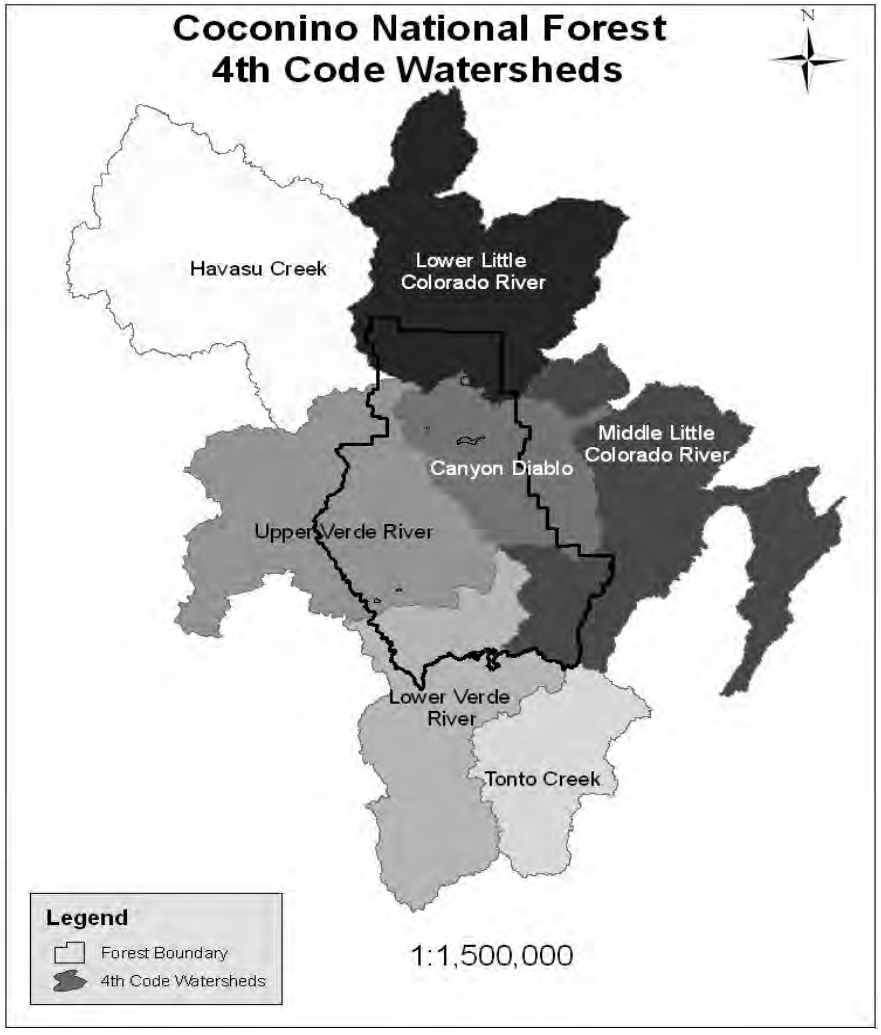

Figure 2: 4th code watersheds of the Coconino National Forest

Airsheds: An airshed is a geographic area representing part of the atmosphere that behaves in a consistent way with respect to the dispersion of emissions. Airsheds are boundaries for establishing and monitoring air quality standards with respect to human health and the environment. Locally, airsheds are represented by watershed boundaries (ridges). Air tends to move down drainages when land cools at night and up drainages during the day as the land warms.

The Coconino lies within two airsheds defined by the Arizona Department of Environmental Quality (ADEQ): the Little Colorado River and Verde River airsheds (Appendix B).

The Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for six pollutants affecting human health (U.S. Environmental Protection Agency 1999). The Forest is responsible for meeting these national standards, as well as state standards, and other federal and state regulatory requirements for air quality. This includes managing and mitigating air pollution from Forest activities, such as prescribed fire.

The Clean Air Act assigns the Forest Service an —affirmative responsibility" to protect federal Class I areas from adverse impacts created by external sources of air pollution. This responsibility requires coordination with the EPA and state, county or tribal air regulatory agencies such as ADEQ.

Sycamore Canyon Wilderness is the designated Class I area that overlaps a portion of the northwest side of the Forest. Class I areas are political boundaries that are represented only by the air directly above each individual wilderness. Class I air quality is affected by pollutants generated from within the wilderness, such as smoke from fires, and also by pollutants that flow into the area from other sources. This might include wood smoke from homes and prescribed fire. Long range transport of pollutants from metropolitan areas and large industry is also possible.

SURROUNDING LANDSCAPE

The degree to which the Forest provides for ecosystem and species diversity relative to the surrounding area is the _ecological niche'. The ecological niche is described by examining the various ecological communities that are represented within and outside the boundaries of the Forest and by analyzing the distribution of these communities and departures from reference conditions.

Terrestrial Systems

Analysis of the surrounding landscapes was completed using a national ecological hierarchy (Bailey 1996, Cleland et al. 1997). Within this hierarchy, ecological land units can be mapped and described as a series of nested units based on similar environmental factors. Ecoregions are areas of regional extent that share common climatic and vegetation characteristics.

Areas within an ecoregion are subdivided into provinces. Provinces are controlled primarily by continental weather patterns such as the length of the dry season and duration of cold temperatures, similar soils, and dominant potential natural vegetation. Approximately 30% of the

Forest acres are classified as Colorado Plateau Semi-Desert Province and 70% as Arizona-New Mexico Mountains Semi-Desert - Open Woodland - Coniferous Forest - Alpine Meadow Province.

Areas within a province are sub-divided into sections. Sections describe broad areas of similar sub-regional climate, geologic origin, composition, and development, local topography, and drainage networks. Figure 3 shows the majority of the Forest (71%) in the White Mountains – San Francisco Peaks – Mogollon Rim (M313A) section with lesser proportion in the Tonto Transition (313C) section (26%), and the least amount in the Painted Desert (313D) section (3%). Remaining lands within the sections are owned or managed by other National Forests, the states of Arizona and New Mexico, Bureau of Land Management, National Park Service, Department of Defense, several tribes, and numerous private entities.

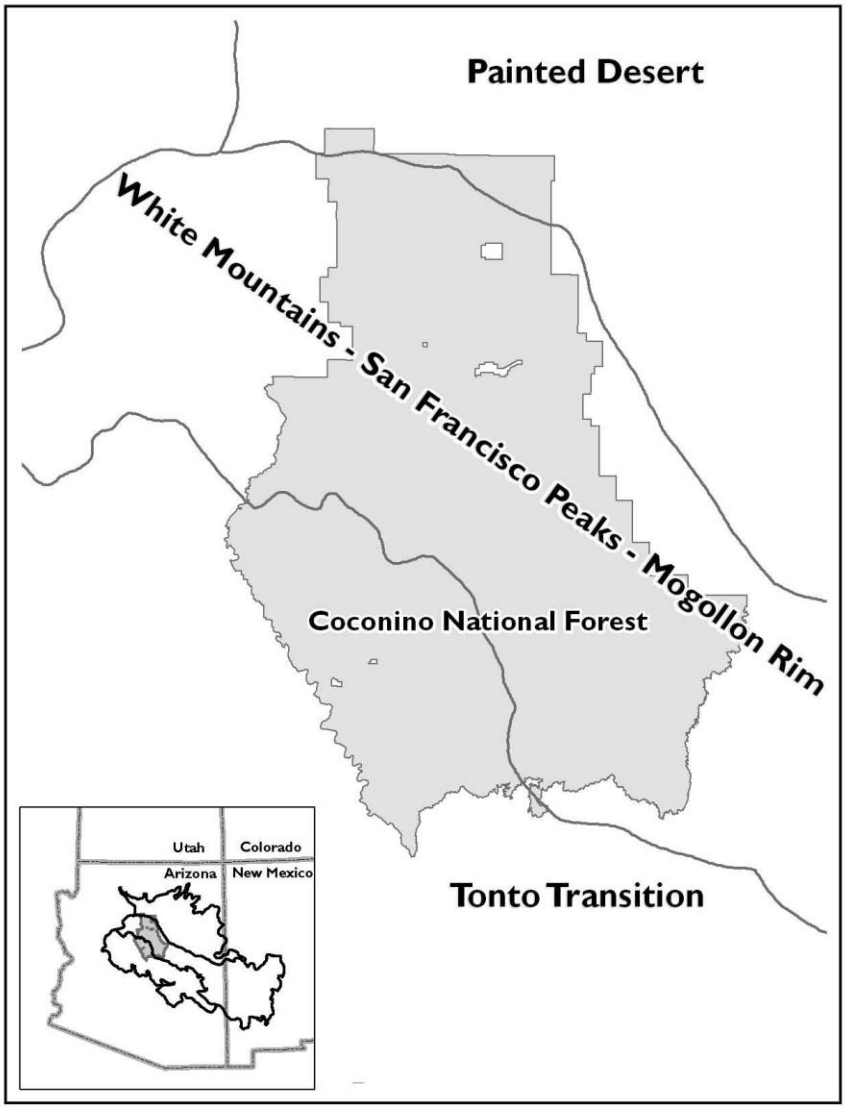

Figure 3: Coconino National Forest in the context of Bailey's Sections

Table 1 shows the relationship of the Forest to the three ecological sections in which it resides. Overall, the sections total nearly 30 million acres (column three). The Coconino occupies only six percent of these three sections (column six).

Table 1: Proportion of Coconino NF lands within three ecological sections

Ecological Section Name	Section	Total Section Acres	Off-Forest Acres	On-Forest Acres	% of section on-Forest
White Mountains-San Francisco Peaks-Mogollon Rim	M313A	13,474,691	12,163,646	1,311,045	9.7%
Tonto Transition	313C	7,555,052	7,083,781	471,271	6.2%
Painted Desert	313D	8,929,244	8,868,861	60,383	0.7%
Grand Totals:		29,958,987	28,116,288	1,842,699	6.2%

As mentioned previously, information in Table 1 shows that the ecological niche of the Coconino is most prominent in the White Mountains-San Francisco Peaks-Mogollon Rim section where the contribution towards ecological sustainability is measured as nearly 10% of the entire section. This means that the primary niche of the Coconino National Forest is providing sustainable conditions for the ecological communities and processes that represent the White Mountain-San Francisco Peaks-Mogollon Rim section and secondarily providing sustainable conditions for the ecosystems within the Tonto Transition and Painted Desert sections.

Ecological sections

The following paragraphs describe the three ecological sections found on the Coconino and surrounding landscapes. These are summarized from McNab and Avers (1994).

White Mountain-San Francisco Peaks-Mogollon Rim section (71% of Forest)

Geomorphology. This section is in central and eastern central Arizona and west-central New Mexico, on the Colorado Plateau. Geomorphic processes active in this section involve recent volcanism, including basalt lava flows, cinder cone eruptions, and volcanic ash. Major landforms include mountains, plains, plateaus, and hills. Major landform features include the San Francisco Mountains, White Mountains, and Jemez and Mogollon Mountains. Elevation ranges from 6,000 to over 12,600 feet.

Climate. Precipitation ranges from 20 to 32 inches plus annually, with over half during the winter. Temperatures average 40° to 57° F although winter temperatures vary through the section and can be cold. This is the primary watershed for much of Arizona and western New Mexico. Ground water is limited and usually deep below the surface. Several large streams are perennial and much water is stored in reservoirs or small artificial lakes. The growing season ranges from less than 50 to 110 days.

Vegetation. Plant communities vary over a soil temperature and moisture gradient with ponderosa pine and gambel oaks on relatively warm and dry sites; white fir and Douglas-fir forests on cool, moist sites; and Engelmann spruce and corkbark fir on the coldest, wettest sites.

Disturbance regimes. Natural fire occurred in ponderosa pine about every 3-10 years but fire suppression has lengthened the fire return interval. This has led to a higher canopy cover and increased fuel loads, resulting in a less resilient ecosystem and increased hazard of wildfire.

Tonto Transition section (26% of Forest)

Geomorphology. The Tonto Transition section is located in the highlands of central Arizona below the Colorado Plateau and above the basins of the Sonoran Desert. Volcanic activity and sedimentary deposition were major geomorphic processes. Lava flows, plugs, dikes, and relatively flat sedimentary deposits resulted. Major landforms are mountains, hills, scarps, and some plains. Major landform features include the Mazatzal Mountains, Black Hills, Aquarius Mountains, Bradshaw Mountains, and the Superstition Mountains. Elevation ranges from 3,000 to 7,400 ft.

Climate. Precipitation ranges from 10 to 25 inches annually, with more than half of the precipitation falling during the winter. Winters are mild below about 6,800 ft and cold at higher elevations. The growing season lasts 70 to 170 days.

Vegetation. Vegetation consists of interior chaparral (mix of deciduous and evergreen shrubs) on coarse igneous parent materials and steep slopes. There are piñon juniper woodlands on elevations higher than about 4,200 ft; ponderosa pine occurs in frigid and limited mesic soil temperature regimes at higher elevations. Low elevation vegetation consists of semi-arid grasslands and desert shrub-scrub communities.

Disturbance Regimes. The natural fire frequency is highly variable, ranging from 2 to 100 years, depending on aspect, elevation, soil moisture, and plant composition. Flash floods and droughts are common.

Painted Desert section (3% of Forest)

Geomorphology. The Painted Desert section is located on the Colorado Plateau. Sedimentary deposition followed by tilting and erosion created the striking plateaus characteristic of this section. Major landforms are plains, hills, canyon lands, and valley plains. Elevation ranges from 4,000 to 7,000 feet.

Vegetation. Grasslands occur at lower elevations and piñon juniper occurs at higher elevations. Saltbush and greasewood occur in dry areas with soils that contain higher amounts of salt and calcium carbonate.

Climate. Precipitation ranges from 8 to 20 inches annually, with about 45% of the precipitation falling during the winter. Winters are generally cold. The growing season lasts 100-170 days. Water is scarce, and the main rivers are intermittent. Water is commonly stored in reservoirs.

Disturbance regimes. Fires are variable in frequency and intensity. Flash floods and drought are common.

Ecological subsections

Subsections are a further division of sections and describe areas with similar surface geology, character of rock formation, geomorphic process, soil groups, subregional climate, and potential natural vegetation communities (McNab and Avers 1994). Subsections are smaller in size and more useful in planning at a smaller scale. Figure 4 shows the outline of the Forest in relationship to sections and subsections. The thicker lines are the named section boundaries and the eight subsections are patterned or shaded.

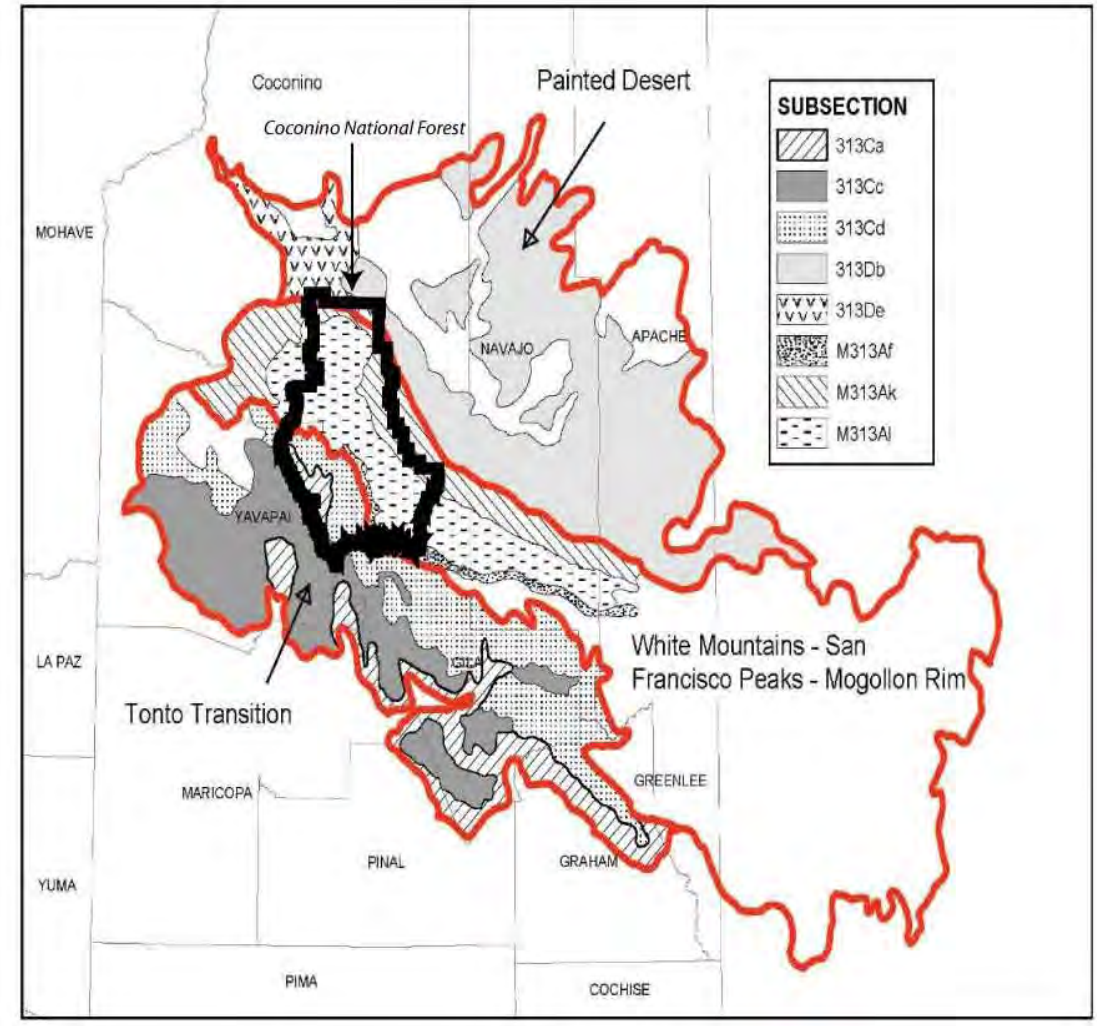

Figure 4: Coconino National Forest in relationship to sections and subsections.

The Coconino lies across portions of three subsections within the White Mountains-San Francisco Peaks-Mogollon Rim section, primarily the Coconino Plateau Coniferous Forest; within three subsections in the Tonto Transition section; and within two subsections in the Painted Desert section.

Aquatic Systems

Perennial streams[1] are unevenly distributed across all 4th code watersheds. Table 2 lists the watersheds, their proportional extent, and proportional extent of perennial streams. Information in the fifth column shows that perennial streams occur mainly in four out of seven (57%) 4th code watersheds: the Middle Little Colorado River, Tonto Creek, Upper Verde River, and Lower Verde River with considerably lesser amounts in Havasu Creek, Canyon Diablo, and the Lower Little Colorado River. The highest proportion of Forest stream miles is located in the Middle Little Colorado River 4th code. The Forest has proportional amount of stream miles in the Upper Verde River and Lower Verde River 4th codes relative to the proportion of the watershed found on the Forest.

[1] Perennial streams are streams that have running water year-round.

Table 2: 4th Code watershed, area, perennial stream miles, and proportional extent compared to Coconino NF

4th Code Watershed	Watershed area (acres)	Coconino area (acres)	% Watershed on the Forest	Total Watershed Perennial Stream Miles[2]	Total Watershed Perennial Stream Miles on Forest	% Watershed Perennial Stream Miles on Forest
Havasu Creek	1,877,163	3,085	0.16%	14	0	0%
Middle Little Colorado River	1,614,677	236,676	15%	202	111	55%
Canyon Diablo	767,057	437,120	57%	5	1	17%
Lower Little Colorado River	1,531,388	229,645	15%	5	0	0%
Tonto Creek	670,572	1,122	0.2%	109	0	0%
Upper Verde River	1,604,394	633,371	40%	79	28	36%
Lower Verde River	1,257,765	301,827	24%	194	41	21%
Forestwide Total Contribution to all Watersheds			**19.7%**	**608**	**181**	**30%**

[2] Data from the National Hydrologic Dataset (USGS 2008).

CHAPTER 2: ECOSYSTEM DIVERSITY

This chapter is organized into seven parts. The first four parts address terrestrial systems, temporal and spatial niche analyses, and soils. The fifth part covers aquatic systems, the sixth focuses on airsheds, and the seventh discusses climate change. Detailed information may be found in supporting individual resource reports.

TERRESTRIAL SYSTEMS

This section summarizes current and reference ecological conditions, along with projected trends based on current management. Analyses were conducted on vegetation using:

- *Potential Natural Vegetation Types (PNVTs).* PNVTs are coarse-scale groupings of ecosystem types that share similar vegetation composition, and historic ecosystem disturbances such as fire, drought, and grazing by native species. PNVTs used for this analysis were summarized by Terrestrial Ecosystem Survey of the Coconino NF (USDA Forest Service 1995) and cross walked with the Southwest Regional Gap Analysis Project (U.S. Geological Survey 2004) landcover vegetation data. See Appendix C for PNVT descriptions and Appendix D for generalized maps.

- *Existing mid-scale vegetation types found on the Coconino*. Mid-scale vegetation types were determined using satellite data and were mapped at 1:100,000 scale. The mid-scale vegetation inventory for the Coconino vegetation types analyzed in this report was conducted in 2005 and 2006.

- *Soil types from Terrestrial Ecosystem Survey (TES) data for the Coconino.* Terrestrial Ecosystem Survey information referenced in this report is specific to the Coconino. It maps terrestrial ecological units based on soil types, existing vegetation and climate (USDA Forest Service 1995).

- *Landscape Fire and Resource Management Planning Tools (LANDFIRE*). LANDFIRE vegetation dynamic models were used to describe historical or reference vegetation conditions. Fire regime condition class (FRCC), as mapped by LANDFIRE, was a measure of the difference or departure between current vegetation composition and structure from the historic reference condition (Rollins and Frame 2006).

- *Ecosystem Condition Class.* This measure is similar to fire regime condition class and was used to evaluate the departure of projected future condition (Weisz et al 2009).

To evaluate ecological conditions, PNVTs and mid-scale vegetation types were compared to identify existing departures from reference conditions. Comparisons and projected trends were also made for fire regime condition class, insects and disease, and invasive or noxious weeds. Additionally, analyses incorporated multi-scale assessments that included areas outside the Coconino NF.

Fire regime condition class (FRCC) was examined by looking at natural fire regimes[3] (USDA Forest Service 2009) which are classified based on average number of years between fires (fire frequency) combined with the severity (amount of replacement) of the fire on the dominant overstory vegetation.

Each PNVT was categorized into one of three FRCCs that describe degree of departure from reference conditions. This departure corresponds with changes to key ecosystem components that may occur, such as vegetation characteristics (i.e., species composition, structural stage, stand age, canopy closure, and mosaic pattern); fuel composition; and fire frequency, severity, and pattern. To compute FRCC, the LANDFIRE Rapid Assessment Program and the National LANDFIRE Datasets only utilized the departure of vegetation characteristics from reference conditions to interpolate missed fire return intervals and expected fire severity. In some cases, fire records further refined FRCC on the Forest. The three FRCCs are:

- *FRCC 1.* Conditions are within the historic range of variability. Effects of a wildfire and other disturbances are similar to those that occurred historically. Composition and structure of vegetation and fuels are similar to the natural and historic regime. Risk of losing key ecosystem components (e.g. native species, large trees, and soil) is low.

- *FRCC 2.* Moderate departure. Effects of a wildfire and other disturbances are not representative of those that occurred historically. Composition and structure of vegetation, and fuels, are dissimilar to the natural and historic regime. Risk of losing key ecosystem components is moderate.

- *FRCC 3.* High departure. Risk of losing key ecosystem components is high.

Vegetation

A Forest Service regional process provided guidance on evaluating ecological sustainability by using PNVTs as the framework for vegetation analysis (USDA Forest Service 2006b, 2008c). Vegetation is the primary terrestrial ecosystem component selected for analysis because it is manipulated by management and affected by natural processes. Vegetation also represents habitat for wildlife and provides the necessary link to species diversity.

Regional PNVT distributions on the Southwestern Region (Region 3) National Forest System lands and across land ownership throughout Arizona and New Mexico were analyzed by The Nature Conservancy (TNC) (Vander-Lee et al. 2006). PNVTs in this report were summarized from the Coconino Terrestrial Ecosystem Survey and then cross walked with Southwest Regional Gap Analysis Project (SWReGAP)[4] land vegetation data. The Coconino‘s Terrestrial Ecosystem Survey data were used for PNVT mapping because of their relevance to site potential, vegetation composition, and historic disturbance patterns for each PNVT. PNVTs on the Forest are displayed in Table 3.

[3]A natural fire regime is a general classification of the role fire would play across a landscape in the absence of modern human mechanical intervention, but including the influence of aboriginal burning (USDA Forest Service 2006b).

[4] SWReGAP was initiated in 1999 as a multi-institutional cooperative effort to map and assess biodiversity for a five-state region, comprising about 560,000 square miles in the southwestern U.S. A key task was the development of a seamless landcover map for the region and the collection of other pertinent bio-physical spatial data.

Table 3: Extent and percentage of PNVTs on Coconino National Forest

Major PNVT Description	Forest Acres	% of Forest
Semi-Desert Grasslands	147,573	8.0
Great Basin Grasslands	94,277	5.1
Interior Chaparral	50,687	2.8
Piñon Juniper Evergreen Shrub	300,154	16.3
Piñon Juniper Woodland	301,675	16.4
Ponderosa Pine	807,424	43.8
Dry Mixed Conifer	79,060	4.3
Montane/Subalpine Grassland	24,199	1.3
PNVTS <1% of Forest		
Cottonwood Willow	2,017	0.1
Mixed Broadleaf Deciduous	2,562	0.1
Wetland Cienega	1,140	0.1
Montane Willow	557	0.0
Desert Communities	6,339	0.3
Spruce Fir	13,942	0.8
Alpine Tundra	941	0.1
*Acres do not sum to Forest total because categories of Urban/Agriculture, Water, and Disturbed/Altered are not displayed.		

Characterizations of PNVTs, their historic range of natural variability, and vegetation state and transition modeling for the largest vegetative communities in the Region are included in the supporting vegetation specialist report (USDA Forest Service 2009c). Modeling projected trends in state and transitions were derived through the use of the Vegetation Dynamics Development Tool (VDDT) (ESSA Technologies Ltd. 2007). VDDT software is a non-spatial model that allows the user to model vegetation change over time as a series of vegetative states that differ in structure, composition, and cover, and to specify the amount of time it takes to move from one vegetative state to another in the absence of disturbance. Various disturbance agents affecting the movement of vegetation between states (or transitions) are incorporated (e.g. surface fires, stand-replacing fires, grazing, insect outbreaks, drought events, etc.). By varying the types and rates of disturbance across the landscape, the effects of different disturbance regimes, such as historic and current fire regimes, or different management treatments, such as fires for resource benefit (wildland fire use), fire suppression, prescribed burning, and mechanical fuel treatments, on vegetation can be investigated (Smith and Schussman 2007). Input data used in modeling came directly from the Coconino‘s forest management activities over the last 20 years. These

vegetation communities are included in the temporal niche analysis that follows below. Current condition is also considered at broader scales in the spatial niche analysis.

LANDFIRE informed the ecological assessments for the following PNVTs: Cottonwood Willow Riparian, Desert Communities, Mixed Broadleaf Deciduous Riparian, Great Basin Grassland, Piñon Juniper Evergreen Shrub, Piñon Juniper Woodland, and Montane/Subalpine Grassland. The Nature Conservancy characterizations and models were used for: Semidesert Grassland, Interior Chaparral, Ponderosa Pine, Dry Mixed Conifer, and Spruce-fir PNVTs. Both LANDFIRE and TNC models were used to analyze change between reference and current conditions to assess overall ecological sustainability. Both overall ecosystem departure and individual vegetation state departure were analyzed. Ecological assessments were not developed by The Nature Conservancy or LANDFIRE for Wetland/Cienega, Montane Willow Riparian, or Alpine Tundra due to their small extent across the Southwestern Region, and instead, a variety of publications were used to describe ecological conditions:

- Alpine Tundra - Merriam and Seineger 1890, Little 1941; Schaack 1970; Moir 2006,
- Montane Willow Riparian Forest - Goodwin 2005, 2006, and 2007, and USDA Forest Service 2009b, and
- Wetland Cienega - USDA Forest Service 2009b.

TEMPORAL NICHE ANALYSIS

The ecological niche is described by both examining the various ecological communities that are represented spatially by comparing portions within and outside the boundaries of the Forest, as well as temporally by analyzing the distribution of these communities and departures from reference conditions. Temporal niche analysis examines time-related factors (i.e. the current departure of ecological communities from reference conditions and the projected trend in the future under current management). Trend was described as _towards reference conditions', _away from reference' or _static'. We used the term _static' to describe a trend that was not getting worse or better. A highly departed ecosystem with a static trend is of concern because it is expected to remain highly departed under current management.

We analyzed vegetative characteristics using the historic range of variation or variability (HRV) of PNVTs as an ecological point of reference (reference condition), and mid-scale vegetation mapping for current forest conditions. This allowed us to make inferences about how current conditions may be related to past and present management practices, climatic variability, and ecological sustainability. For example, encroachment and establishment of woody species in grasslands is an indicator that grasslands may be outside their HRV and ecological sustainability may be threatened. Ecosystem processes, such as disturbance regimes of fire, drought and insects, wind, flooding, etc, were also evaluated within the framework of HRV.

HRV is a description of the change over time and space in the ecological condition of the PNVTs and the ecological processes that shape those types. PNVTs represent the vegetation type and characteristics that would occur when natural disturbance regimes and biological processes prevail (Smith and Schussman 2007). Descriptions of HRV also focus on the influence of humans on changes in PNVT characteristics as described in the literature (Schussman 2006,

Schussman 2006a, Schussman 2006b, Schussman and Gori 2006, Schussman and Smith 2006, Smith 2006, Smith 2006a, Smith 2006b, Smith 2006c, Smith 2006d, Smith 2007, and Gori and Bate 2007). Departure values represent the difference between current and reference conditions for individual characteristics. These were calculated for major PNVTs on the Forest. Individual vegetation characteristics that were evaluated were: species composition, structure (vegetation classes) of the dominant life forms (grass, shrub, tree), and the disturbance processes that define each PNVT. A PNVT with a 90% departure value is considered to be highly departed, or deviated from reference conditions. A PNVT with a 10% departure value is considered to have a low departure from reference conditions.

An example of how departure values were calculated based on the difference between current and reference conditions is shown in Table 4.

Table 4: Example of departure value

State	Successional Structure, Composition & Cover Class	Reference % composition	Current % composition	Similarity value[5]	Departure value[6]
A	Early development, open canopy	5	9	5	
B	Mid development, young to mature trees, closed canopy	55	28	28	
C,D	Late development, mature and old trees, open to closed canopy	40	63	40	
		100	100	73	27%

A summary of Forest vegetation departures in structure and composition is provided below (USDA Forest Service 2009c). It is followed by a table that displays departure, trends, and departure values, and then narratives that discuss individual PNVTs in more detail.

There has been a significant shift to woody vegetation in all three grasslands:

- *Semidesert Grassland.* Significant shift to shrubs and trees. Trend away from reference conditions.
- *Great Basin Grassland.* Significant shift to shrubs and trees on 17% of the PNVT with unknown trend.
- *Montane Subalpine Grassland*. Shift to trees with unknown trend.

Changes to age class diversity, species composition, or canopy cover characterize the Piñon Juniper vegetation types:

- *Piñon Juniper Evergreen Shrub*. Significant shift to closed canopy trees with loss of herbaceous understory with trend away from reference conditions.

[5] The Similarity Value = lower of Current or Reference values by structural class.
[6] The Departure Value (%) = (100 – Sum of similarity values).

- *Piñon Juniper Woodland*. Significant shift to small to medium sized trees with loss of herbaceous understory with trend away from reference conditions.

Forest vegetation has experienced overall shifts in tree age class diversity, canopy, and tree composition:

- *Ponderosa pine*. Significant shift to closed medium aged forest with loss of herbaceous understory and tree age diversity with a trend away from reference conditions.
- *Dry mixed conifer.* Significant shift to closed medium aged forest and there are shifts in species composition as well. There is a loss of herbaceous understory, ponderosa pine, and tree age diversity; and an increase in shade tolerant species. Trend is away from reference.
- *Spruce fir.* Large fires burned through this PNVT in the early 1900's. Since then it has developed into young to medium aged forest with regeneration. Trends toward reference conditions.

Riparian vegetation has experienced shifts in vegetation age diversity and canopy cover with unknown trends:

- ***Cottonwood Willow Riparian.*** **Shift to small and medium diameter trees with closed canopy and large trees with open canopy. Shift away from open grown tree regeneration and larger trees with connected canopies.**
- ***Mixed Broadleaf Deciduous Riparian.*** **Shift to small and medium diameter trees with closed canopy. Shift away from open grown tree regeneration, large trees with connected canopies, and medium to very large trees with open canopies.**
- ***Montane Willow Riparian.*** **Shift to increasing canopy cover and more trees and away from early seral vegetation.**

An overriding theme in all major PNVTs is the loss of herbaceous understory compared to reference conditions.

Table 5 shows the PNVT departures when current vegetative composition and structural conditions are compared to reference conditions. PNVTs found to be highly departed were: Ponderosa Pine, Dry Mixed Conifer, Semidesert Grassland, and Desert Communities. Moderately departed communities include the two Piñon Juniper types, three riparian types, and Montane Subalpine Grassland and Spruce Fir. The vegetation types most similar to reference conditions (with low vegetative departures) are Great Basin Grassland, Interior Chaparral, Wetland Cienega, and Alpine Tundra.

Table 5: Summary of vegetative departure and trend from reference conditions

PNVT	Reference Source	Departure Values[7]	Departure from Reference Condition[8]	Projected Future Trend Under Current Management
Cottonwood Willow Riparian Forest	LANDFIRE	49	Moderate	Unknown
Desert Communities	LANDFIRE	80	High	Unknown
Semi-Desert Grasslands	Vander-Lee et al 2006	100	High	Away
Mixed Broadleaf Deciduous Riparian Forest	LANDFIRE	43	Moderate	Unknown
Great Basin Grassland	LANDFIRE	18	Low	Unknown
Interior Chaparral	Vander-Lee et al 2006	1	Low	Static
Piñon Juniper Evergreen Shrub	LANDFIRE	44	Moderate	Away
Piñon Juniper Woodland	LANDFIRE	56	Moderate	Static
Wetland/Cienega	USDA Forest Service 2009b	64	Moderate	Unknown
Ponderosa Pine	Vander-Lee et al 2006	99	High	Away
Montane Willow Riparian Forest	Goodwin 2005, 2006, 2007, USDA Forest Service 2009b	64	Moderate	Unknown
Dry Mixed Conifer	Vander-Lee et al 2006	99	High	Away
Montane Subalpine Grassland	LANDFIRE	33	Low	Unknown
Spruce Fir	Vander-Lee et al 2006	55	Moderate	Towards
Alpine Tundra	Merriam and Seineger 1890, Little 1941; Schaack 1970; Moir 2006	Not calculated	Low	Away

Individual PNVT departures on the Forest

Cottonwood Willow Riparian Forest

Cottonwood Willow Riparian Forest is patchily distributed along the lower elevation reaches (2,800 – 3,600 feet) of perennial streams including the Verde River, Lower Oak Creek, Wet Beaver Creek, Fossil Creek and West Clear Creek, although this PNVT is also found along other perennial and intermittent tributaries. Dominant vegetation includes narrow leaf cottonwood and a variety of willows. Various grasses and forbs are usually present. In general, riparian vegetation occurs along the stream channel and associated higher stream terraces, which support

[7] Departure values for Alpine Tundra were not calculated due to its small extent in the Region.
[8] Departure was assessed as Low (0 – 33%), Moderate (34 – 66%) or High (> 66%).

a mix of riparian and upland vegetation, including mesquite and desert willow (USDA Forest Service 1995).

Reference Condition: Historically, there were more acres of Cottonwood Willow Riparian Forest. The v**egetation structure was fairly evenly distributed between seedlings and saplings up to large trees. About 60% of the PNVT had a closed canopy (Table 6).**

Table 6: Reference and current vegetation conditions for Cottonwood Willow Riparian Forest PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Seedling, saplings, shrubs; post reproduction, open canopy	20	5	5	
B	Shrub, small & medium diameter trees, closed canopy	25	60	25	
C	Medium and very large diameter trees, closed canopy	35	1	1	
D	Medium and very large diameter trees, open canopy	20	35	20	
		100	100	51	49%

Flooding and drought were two major disturbance processes. Riparian areas flooded more frequently than higher lying terraces, although major flood events occurred infrequently (USDA Forest Service 1995, Hereford 2007). The seasonality and the quantity of water in floods are key factors in the germination and establishment of riparian vegetation. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Cottonwood Willow Riparian Forest currently covers 0.1% (2,017 acres) of the Forest. Much of the PNVT along the Verde River, lower Oak Creek and lower Wet Beaver Creek is privately owned or managed by Arizona State Parks

This PNVT is moderately departed from reference conditions, primarily from having insufficient vegetation such as grass, open grown shrubs, and seedling/saplings. Mid-scale analysis included upland species that mix with riparian vegetation along higher stream terraces. There is slightly higher canopy cover compared to reference conditions.

Current major disturbances: Water diversions and increasing human development in the watersheds have affected quantity and seasonality of historical flood regimes, eliminating or reducing native species that provide competition to non-native plants.

There are few weed species, but some such as Russian knapweed, yellow starthistle and Malta starthistle, tamarisk, tree of Heaven and giant reed rank high for invasiveness, so this PNVT is considered moderately departed from reference condition for weeds[9].

Projected Future Condition and Trends: Existing gallery forests are projected to be unsustainable because of their location above the dropping water table and instream flows. Trends for this PNVT regarding future regeneration of small trees, shrubs or development of replacement gallery forests are unknown due to lack of data. The projected trend for noxious and/or invasive weeds is away from reference conditions under current management. Plants such as tamarisk, giant reed, and tree of Heaven will limit and eventually cause a decline in quality of existing vegetation by reducing native cottonwood and willow regeneration potential. Instream flows may be reduced as a result since these nonnative, woody plants draw more water out of the water table than native trees (Hart 1999, DiTomaso 1998, Zimmerman 1997, Tesky 1992). In addition, there have been significant increases in fire intensity and severity in this PNVT in the southwest due to invasive species, primarily tamarisk and Russian olive. Severe fires remove cottonwoods from burn areas and convert these sites to a non-native species mix.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Although gallery forests are relatively more abundant than in reference conditions they are projected to decline in the future due to dropping water tables and possible shifts in instream flow conditions. Native plant diversity is expected to shift towards nonnative species. The structure that is currently made of young willows and cottonwoods may be replaced by nonnative plants such as tamarisk and giant reed.

Desert Communities

Desert Communities occurs in the Verde Valley where Upper Sonoran Desert species merge with the Forest. It ranges from 2,700 to 4,000 feet in elevation. Much of the area is old alluvial, Pliocene lakebed deposits developed from limestone, sandstone and clays, intermixed with volcanic ash layers. It occurs in creosote dominated alluvial positions and on old stream terraces adjacent to Cottonwood Willow Riparian Forest. Some areas may be barren with abundant sand, rock, gravel, scree or talus.

Vegetation includes desert scrub, grasses and some succulents, but is dominated by creosote bush and mesquite and may include, cat claw acacia, triangle leaf bursage, saltbush, blackbrush, iodine bush, splitleaf brickellia, desert broom, desert willow, Apache plume, cheesebush, barrel cactus, hedgehog cacti, cholla, and prickly pear, and tobosa grass (USDA Forest Service 1995). The Endangered Arizona cliffrose occurs in a very restricted portion of the PNVT, while several other rare endemic[10] native plant species are distributed more widely within particular soil types

[9] The relative departure is based on the number of weed species known within the PNVT, total acreages of infestations within the PNVT, dispersion of the weeds across the PNVT, and the invasiveness of each species. The invasiveness or seriousness of each species was determined from literature and local observations and was based on biological and ecological characteristics of the plant, such as number of seeds produced, ability to vegetatively reproduce, competitiveness, rate of spread. It is assumed that there were no invasive and/or noxious weeds at the time of white settlement, which was used as the reference point for reference conditions (USDA Forest Service 2008).

[10] Occurrence limited to a particular geographic area.

of this PNVT. The extreme range of climate variability, influenced by temperature and precipitation can cause temporary, and very local, changes in species composition in this PNVT (Sheppard et al. 1999).

Reference Condition: This PNVT had a larger extent historically. Much of it is now private land and has been developed. Historically, 20% of the PNVT was comprised of a combination of shrubs with understory herbaceous vegetation and 75% was sparsely vegetated (Table 7). Five percent of the PNVT was in an early seral stage.

Table 7: Reference and current vegetation conditions for Desert Communities PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Earty seral herbs & shrubs	5	0	0	
B	Late seral herbs & shrubs, > 15% canopy	20	100	20	
C	Late seral shrubs, sparsely vegetated, < 15% canopy	75	0	0	
		100	100	20	80%

No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Desert Communities covers approximately 0.3% (6,339 acres) of the Forest. According to mid-scale data, it is currently 100% late seral herb and shrubs types. Current condition mainly consists of closed canopy late seral herbaceous vegetation and shrubs. Open canopy late seral shrubs are lacking from the landscape according to LANDFIRE. This PNVT is considered highly departed from reference conditions.

Desert Communities has few weed species although some rank high for invasiveness and non-native annual grasses (such as red brome) are widely dispersed at low densities. Non-native grasses can cause major changes in ecosystem integrity, if not controlled (Seig et al. 2003, Bradford and Lauenroth 2006, Link et al. 2006, Kulmatiski et al. 2006).

Projected Future Condition and Trend: Trend is unknown for vegetation structure and composition. While this PNVT‘s fire regime predicts a high severity with longer fire return intervals, invasive species are likely to lead to larger extents of high severity fire per fire occurrence, as well as a fire frequency outside the historic range of variability.

This PNVT is moderately departed from reference conditions due to the current presence of weed species and is projected to move away from reference conditions in the future. The opportunity for spread and colonization of new sites is high due to the presence of high use roads such as US 89A and State Route 179, which have numerous weed infestations. This PNVT is also impacted by the increased human populations in the Verde Valley, increased recreation impacts, and increased potential for human-caused fires (USDA Forest Service 2008b).

Comparison of Reference, Current, and Projected Future Conditions and Trends: Extent and continuity of the Desert Communities PNVT has decreased relative to reference conditions because of activities on the multiple ownerships on which it lies, mainly State and private. A shift in understory species composition towards nonnative species is likely due to the proximity and rapid growth of the Verde Valley communities. An increase in the frequency and severity of wildfires is a logical consequence of increased abundance and distribution of nonnative annual grasses.

Semi-Desert Grassland

The Semi-Desert Grassland PNVT occurs throughout southeastern and central Arizona and southern New Mexico from 3,000-4,500 feet and is bounded by the Sonoran Desert at its lowest elevations and woodlands or chaparral at its highest elevations. Current vegetation is dominated by perennial bunchgrasses, shrubs and trees. Forbs may include various buckwheat species. Shrubs may also be present and abundance and species composition varies, but may include crucifixion thorn, velvet mesquite, cat claw mimosa and turbinella oak. Trees may include Utah juniper and red berried juniper (USDA Forest Service 1995).

Reference Condition: This PNVT had a larger extent historically. Much of it is now private land. Historically, this community was dominated by open perennial bunchgrasses with about 25% grass regeneration. Shrubs and trees were not well represented in the landscape. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Semi-Desert Grassland covers 8.0% (147,573 acres) of the Forest. Currently, shrubs and trees are well represented (as shown in Table 8) and analysis using mid-scale data suggests it is highly departed from reference conditions (Schussman 2006). About 30% of the grasslands on the south end of the Forest, on the Red Rock Ranger District, have become so shrub invaded that they have likely undergone a type conversion with little potential to be restored to open native grassland condition (Vander-Lee and Smith 2006).

Table 8: Reference and current vegetation conditions for Semi-Desert Grassland PNVT

State	Successional Structure Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Grass forb regeneration	24	0	0	
B	Open perennial bunchgrass	76	0	0	
C	Perennial bunchgrass w/ shrubs and trees, open canopy	0	49	0	
D	Shrubs and trees w/ perennial bunchgrasses	0	51	0	
		100	100	0	100%

Current fire frequency is outside the historic range of variability and trending away from reference conditions, possibly due to fire suppression. Non-native invasive species may reach a critical mass that increases both fire frequency and flame front intensity. This, however, has not yet occurred.

During drought, vegetation production is significantly curtailed and litter may increase as plants die, resulting in increased susceptibility to fire. The Semi-Desert Grasslands PNVT currently has few weed species, but some rank high for invasiveness, and one (red brome) is widely dispersed at low densities and can cause major changes in ecosystem integrity if not controlled. This PNVT is moderately departed from reference conditions for invasive weeds.

Projected Future Condition and Trend: Under current management, the significant shift to shrubs and trees is likely to continue because continued lack of fire promotes the maintenance of woody vegetation. The projected trend for invasive and/or noxious weeds is away from reference conditions. The presence of non-native annual grasses such as red brome could cause major changes in ecosystem integrity if not controlled.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Open perennial grasslands and herbaceous understory are now present only in trace amounts. Lack of fire has contributed to, and will likely continue, a shift to shrub- and tree-dominated grasslands which were largely absent in the historic landscape. This may shift more of the PNVT into FRCC 2 and 3. Native herbaceous species composition could shift if nonnative invasive grasses expand, which could increase the frequency of fires, which have higher severity due to increased shrubs and trees. Higher severity fires can create disturbed areas that facilitate the spread and establishment of nonnative plants.

Mixed Broadleaf Deciduous Riparian Forest

The Mixed Broadleaf Deciduous Riparian PNVT covers less than 1% (2,562 acres) of the Forest. Found between 3,600 and 5,800 feet in elevation, it is patchily distributed across the Forest and includes higher elevation portions of West Clear Creek and Oak Creek and associated tributaries. It consists of a vegetation mix of riparian woodlands and shrublands with various dominant species, depending on site specific characteristics. Vegetation can include Arizona sycamore, thinleaf alder, willow, Arizona cypress, conifers, box elder, narrowleaf or Fremont cottonwoods, velvet ash and often contains oaks and conifers from adjacent uplands.

Reference Condition: This PNVT had a larger extent historically. Historically, this PNVT generally consisted of 10% grass, forbs and shrubs; 30% small to medium sized trees with closed canopy, 25% small trees with open canopy; 15 % medium to very large trees with open canopy and 20% very large trees with closed canopy (Table 9).

Table 9: Reference and current vegetation conditions for Mixed Broadleaf Deciduous Riparian

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Open with grasses, forbs, seedlings and saplings.	10	11	10	
B	Small to medium diameter trees, closed canopy	30	68	30	
C	Seedling, sapling; small diameter trees, open canopy	25	16	16	
D	Medium to very large diameter trees, open canopy	15	1	1	
E	Very large diameter trees, closed canopy	20	4	4	
		100	100	61	39%

Flooding and drought were two major disturbance processes. Historically, riparian areas flooded frequently with higher lying terraces experiencing fewer floods, and major flood events were uncommon (USDA Forest Service 1995). The seasonality and the quantity of water in floods are key factors in the germination and establishment of vegetation within this PNVT. In drought years, this PNVT would be more susceptible to wildfire from adjacent PNVTs. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Table 9 shows that this PNVT currently differs from reference conditions in having more of the small to medium sized trees with closed canopy, fewer medium to very large diameter trees with open canopy, and fewer very large diameter trees with closed canopy, based on mid-scale analysis. Overall canopy cover is higher and understory is sparser, which results in less favorable conditions for the establishment of early succession species. Similar to the Cottonwood Willow Riparian PNVT, mid-scale analysis also includes some upland species that mix with riparian vegetation along the higher stream terraces. When only riparian deciduous species are evaluated, there is an overabundance of mid aged trees with open canopies and too few medium to large trees (gallery forest). This may be a consequence of large flood events.

Mixed Broadleaf Deciduous Riparian is primarily affected by flooding and drought. The PNVT remains susceptible to wildfire from adjacent PNVTs, particularly in drought years. Ponderosa Pine and Dry Mixed Conifer PNVTs are adjacent in numerous locations. **This PNVT** has few weed species, but some, such as diffuse knapweed, yellow starthistle and Malta starthistle rank high for invasiveness. Non-native annual grasses (including ripgut brome) are widely dispersed at variable densities and can cause major changes in ecosystem integrity if not controlled.

Projected Future Condition and Trend: Vegetative overstory trend cannot be determined because there is no VDDT model available due to the small extent of this PNVT; however, current conditions are likely to persist and natural succession patterns are expected to occur, barring major droughts or fire. This PNVT has low departure for weeds, but is projected to move away from reference conditions. A concern is the presence of non-native annual grasses such as red brome, and ripgut brome because they could cause major changes in ecosystem integrity if not controlled. Fire occurrence could increase as a result, and the plants of this ecosystem are not

adapted to the frequency at which non-native annuals burn (Phillips 1990). The presence of Himalayan blackberry, a very competitive species, is a relict of past homesteading within this PNVT. Himalayan blackberry reproduces vegetatively and its fruits are spread by humans and wildlife, so control is difficult.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Historically, this PNVT was more widely distributed and had a more continuous extent i.e. was less fragmented than it currently is. Portions of it have shifted into private ownership. As the Forest became more actively managed over time, the PNVT has been divided by roads in many locations. Flooding was a major disturbance regime. Wildfire from adjacent PNVTs is also a disturbance factor that could influence the structure and composition of this PNVT because the PNVT is narrow at its upper reaches and contains conifers in its upland terraces. Fire suppression has contributed to an increased likelihood of larger or more severe fires in adjacent PNVTs and connected watersheds, which could affect this PNVT. Sedimentation or increased runoff from these fires could also influence the timing and severity of flooding in this PNVT. An increase in the abundance of nonnative species could result in a shift from native to nonnative understory species.

Great Basin Grassland

Great Basin Grassland (also known as Great Basin/Colorado Plateau Grassland and Steppe) occurs at a lower elevation than the higher elevation grasslands and consists mostly of grasses with interspersed shrubs and encroaching Piñon and juniper trees in areas. Species include: Western wheatgrass, spike muhly, black grama, Indian ricegrass, threeawn, blue grama, fescue, needle and thread, spike fescue, James' galleta and Sandberg bluegrass. Shrubs may include sagebrush, saltbush, Ephedra, snakeweed, winterfat and rabbitbrush. Trees may include sparse one-seeded juniper and Colorado Piñon pine (USDA Forest Service 1995).

Reference Condition: This PNVT had a larger extent historically. Historically, nearly three-fourths of the PNVT was open mid-development grasses and forbs, with about one-fifth of it in late development shrubs and trees with open canopy (Table 10). No invasive and/or noxious weeds were present under reference conditions.

Table 10: Reference and current vegetation conditions for Great Basin Grassland PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early development – recently burned, sparsely vegetated, open canopy	5	0	0	
B	Mid development – grass, forbs, open canopy	73	74	73	
C	Late development – open; some shrubs, seedlings & saplings & some mid-size trees	20	7	7	
D	Mid development – some very large shrubs, closed canopy & some very large trees, open canopy	2	19	2	
		100	100	82	18%

Current Condition: Great Basin Grassland covers 5.1% (94,277 acres) of the Forest. Currently, Great Basin Grassland is similar to reference conditions. Some shrub and tree invasion is occurring along edges of grasslands. There is a shift from small to large tree sizes, primarily in the northeastern part of the Forest (about 17% of the PNVT), near Wupatki National Monument.

Stock tanks have been constructed within wetland cienegas that mainly occur within the Great Basin Grassland PNVT. This has resulted in longer duration of water. Wildlife and livestock concentrate around water, resulting in shifts towards grazing tolerant species; reduction in vegetation height; soil compaction and disturbance; and shifts in abundance, density and vigor of herbaceous species in the vicinity around water within this grassland type.

Great Basin Grassland has few weed species, but some (camelthorn and diffuse knapweed) ranks high for invasiveness. Cheat grass is widely dispersed at low densities and can cause major changes in ecosystem integrity if not controlled. This PNVT is moderately departed from reference conditions for weeds.

Projected Future Condition and Trend: The projected trend for the dominant vegetation is unknown because there currently is no model for this PNVT. The projected trend for noxious or invasive weeds is away from reference conditions. A concern is the presence of non-native annual grasses, such as cheat grass, because they can cause major changes in ecosystem integrity if not controlled. Invasion of weeds is also a high probability for this PNVT due to the proximity of other land ownerships.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Vegetatively, this PNVT is similar to reference conditions although there is a shift in structure and composition to increased shrubs and trees in 17% of the PNVT. This trend is likely to continue in the future due to lack of fire in the surrounding PNVTs. The majority of the PNVT retains open canopy of dominant vegetation. The shift from native to increasing nonnative understory species (cheatgrass and knapweed) is likely to continue in the future. The presence of stock tanks and the associated localized grassland impacts is likely to continue in the future as well.

Interior Chaparral

Typically Interior Chaparral is found at the lower elevations mostly in the Verde River basin. It is located where low-elevation Semi-Desert landscapes transition into Piñon Juniper Evergreen Shrub. Vegetation includes turbinella oak, mountain mahogany, manzanita, desert ceanothus, silk tassel, Stansbury cliffrose, and sumac (USDA Forest Service 1995).

Reference Condition: Historically, this PNVT had about 2% grass and forb regeneration, 5% grass and open shrubs and 93% dense shrubs with a closed canopy with no understory (Table 11). No invasive and/or noxious weeds were present under reference conditions.

Table 11: Reference and current vegetation conditions for Interior Chaparral PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Regeneration, recently burned, and mix of grasses and forbs.	2	2	2	
B	Mix of grass and shrubs, open canopy	5	4	4	
C, D	Mid to late development dense shrubs, no understory	93	94	93	
		100	100	99	1%

Current Condition: Interior Chaparral PNVT covers 2.8% (50,687 acres) of the Forest and is similar to the extent under reference conditions. Current structure, composition and extent are similar to reference conditions. The Interior Chaparral has a few species of weeds and the populations are few in number and acreage. This PNVT is rated low for relative departure of invasive weeds from reference conditions.

Projected Future Condition and Trend: The projected trend for vegetation structure and composition is static. The projected trend for weeds is away from reference conditions because of the anticipated spread of more non-native annual grasses from adjacent PNVTs.

Comparison of Reference, Current, and Projected Future Conditions and Trends: The current structure and composition, including weeds, of Interior Chaparral is similar to reference conditions. The abundance and distribution of nonnative understory species are expected to increase as they encroach from surrounding PNVTs.

Piñon Juniper Evergreen Shrub

Piñon Juniper Evergreen Shrub usually occupies hills, plains, mountains, and escarpments below the Mogollon Rim and ranges from about 4,000-6,900 feet in elevation. It is dominated by an open to closed shrub canopy of evergreen oaks such as turbinella oak, and some tree forms of Emory and Arizona white oak, Stansbury cliffrose, with single needle Piñon pine and Utah juniper co-dominant and some areas of alligator juniper and Arizona cypress. There may be a grassy understory in areas of low tree canopy cover. Herbaceous ground cover is dominated by

warm season grasses including blue and sideoats grama, and needle and thread grass where undisturbed (USDA Forest Service 1995).

Reference Condition: Historically, this landscape was dominated by shrubs and medium to very large open grown trees (Table 12). No invasive and/or noxious weeds were present under reference conditions.

Table 12: Reference and current vegetation conditions for Piñon Juniper Evergreen Shrub PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early development – shrubs, open canopy	5	9	5	
B	Shrub – closed canopy Seedlings, saplings, small trees, open canopy	55	47	47	
C	Medium to old (very large) woody species with grass understory – open canopy	40	4	4	
D	Medium to old (very large) woody species with grass understory – closed canopy	0	40	0	
		100	100	56	44%

Current Condition: The Piñon Juniper Evergreen Shrub PNVT covers 16.3% (300,154 acres) of the Forest, mainly below the Mogollon Rim on the southwestern part of the Forest. It is less extensive now than during reference conditions. Current conditions from mid-scale vegetation analysis indicate a significant shift to closed canopy of trees, only found in contemporary landscapes, which results in a loss of herbaceous understory. The Piñon Juniper Evergreen Shrub PNVT is moderately departed from reference conditions. This PNVT has few species of weeds and the populations are few in number and acreage. Lehmann‘s lovegrass, a perennial non-native grass that increases fire frequency (Phillips 1990), is present in this PNVT. This PNVT is rated low for relative departure from reference conditions for weeds.

Projected Future Condition and Trend: This PNVT‘s vegetation structure and composition is projected to move away from reference conditions over the long-term as the tree canopy closes during the next 100 years. Increasing amounts of non-native grasses could initiate a fire return interval to which native plants are not adapted. This PNVT is slowly trending away from reference conditions with respect to invasive and/or noxious weeds. It is anticipated that invasion of more non-native annual grasses will occur from adjacent PNVTs and, with the additional presence of Lehmann‘s lovegrass, the fire return interval could change to an even higher frequency and intensity than that to which the native species are adapted.

Comparison of Reference, Current, and Projected Future Conditions and Trends: The more open conditions that were present historically are being replaced by closed canopies. Understory vegetation is subsequently reduced. Continued exclusion of fire will perpetuate the trend towards closed canopy. Over time, nonnative weed species from adjacent PNVTs are expected to infiltrate into more open areas. This may prompt a shift to a fire return interval that is more

frequent than what occurred historically. Both fire exclusion and infiltration of weeds may lead to fire severity over a larger area that is outside the historic range of variability.

Piñon Juniper Woodland

Piñon Juniper Woodland is distributed on lower slopes of mountains and upland rolling hills between 5,500 and 7,200 feet elevation, mainly on the north and east portions of the Forest. Colorado piñon pine, Utah and one-seed juniper are most common, with alligator juniper at higher elevations. Shrubs may include Stansbury cliffrose, Gambel oak, saltbush, big sagebrush, and limited areas of turbinella oak and manzanita. Woodland understory includes annual and perennial grasses including blue grama, needle and thread grass, western wheatgrass, and nonnative crested wheatgrass (USDA Forest Service 1995).

Reference Condition: Modeling indicates that the majority of the landscape was open with small, medium, and large trees overtopping an herbaceous understory (Table 13).

Table 13: Reference and current vegetation conditions for Piñon Juniper Woodland PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early successional, grass-forb; post tree reproduction	5	20	5	
B	Small to medium sized trees with closed canopy	10	28	10	
C	Seedling, sapling; small to medium sized trees with open canopy	25	47	25	
D	Medium to very large sized trees with open canopy	50	2	2	
E	Very large sized trees with closed canopy	10	2	2	
		100	100	44	56%

Historically, there was more open canopy in the PNVT, fewer areas of dense trees, more areas with medium to very large trees, and more fires than current. Thus there would have been fewer areas susceptible to insect, disease or drought. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Piñon Juniper Woodland covers 16.4% (301,675 acres) of the Forest. It is less extensive now than during reference conditions. Currently, there is a shift towards small to medium sized trees with loss of herbaceous understory and large trees with open canopy. Recently, approximately 150,000 acres (about 50%) of this PNVT was affected by drought that facilitated Piñon Ips bark beetle infestations. This has resulted in the mortality of piñon in most of the affected area over the past 20 years. This resulted in more open canopies, and increased solar radiation and herbaceous understory production. Since 1996, piñon mortality averaged more than 55% across the Forest, but has been the most severe at low elevations, in stands with

high stand density, in the larger size classes, and in trees with severe Piñon dwarf mistletoe infection. Over stocked stands are susceptible to insect attacks during drought periods. Small piñons will maintain the tree‘s presence in the future. The increase in dead fuels, however, increases the potential for high severity fires.

The Piñon Juniper Woodland has several weed species. Some species, such as diffuse knapweed, yellow starthistle, Malta starthistle, camelthorn and Russian knapweed, are ranked high for invasiveness, but their populations are few in number and acreage, considering the overall acreage of this PNVT. Consequently, this PNVT is rated low for relative departure with respect to weeds.

Projected Future Condition and Trend: Current disturbances maintain departure from historic conditions. The 150,000 acres that were affected by drought and Piñon Ips bark beetle infestations is expected to move towards reference conditions with respect to insect and disease. The other portion of the PNVT that is overstocked, primarily due to fire suppression, is expected to move away from reference conditions. The remaining portion of the PNVT is expected to be static.

Piñon Juniper Woodland is projected to move away from reference conditions with respect to weeds because it is anticipated that an expansion of cheat grass will occur from adjacent Ponderosa pine and Great Basin grassland PNVTs. Although fire is an important disturbance feature of this PNVT, there is a possibility that with the incursion of non-native grasses, the fire return interval could change to an even higher frequency and intensity than that to which the native species are adapted.

Comparison of Reference, Current, and Projected Future Conditions and Trends: A major landscape shift in structure and composition occurred with loss of the majority of piñon over 150,000 acres due to a combination of drought and insects. Under current management, the trend is away from reference. Understory composition is expected to shift if cheatgrass invades from adjacent PNVTs. Lack of fire shifted a once mostly open landscape to areas of increased canopy cover.

Wetland Cienega

Wetland Cienega encompasses basin and swale wetlands, ranging from seasonally to permanently wet and unmapped perennial springs or headwater streams where groundwater intersects the surface, creating pools or channels. Vegetation can include rushes, sedges, flat sedges, spike rushes, and aquatic vegetation in pools. The PNVT includes high elevation (4,200-8,000 feet) meadows, with hydric soils and hydrophytic vegetation that have subsurface flows and are dominated by herbaceous cover (USDA Forest Service 1995).

Reference Condition: These precipitation dependent wetlands are associated with shallow depressions mainly in the vicinity of Anderson Mesa. Composition and structure of vegetation within Wetland Cienega PNVT were influenced by precipitation. Size, margin and depth were influenced by available water. Wetland cienegas were full of water with relatively abundant vegetation in wet years, and some could be completely dry during droughts. Vegetation density was dependent on type of vegetation and amount of water (Table 14).

Table 14: Reference and current vegetation conditions for Wetland Cienega PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early seral post fire replacement vegetation	15	0	0	
B,C	Open to closed shrubs	85	100	85	
		100	100	85	15%

Fire was a rare occurrence although burning could occur during droughts when vegetation was dry and fire moved in from adjacent PNVTs. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: The Wetland Cienega PNVT covers less than 1% (1,140 acres) of the Forest. Wetland Cienega is slightly reduced in extent from reference conditions because some wetlands are under private ownership or managed by other entities. For example, four wetlands have been converted to reservoirs such that water depth, vegetation and persistence of water have substantially changed. These function as lakes, not wetlands. **Precipitation plays the same role as it did historically.**

Wetland structure has been modified by stock tanks, dams and other infrastructure. These features were initially constructed when the area was being homesteaded. They alter the flow and permanency of water so that water depth, perimeter, surface area, vegetation, and persistence of water have changed as a result. Wetland vegetation species composition or abundance has likely adjusted to alterations in depth and persistence of water. The composition of wetland vegetation is assumed to be similar to reference conditions, with bulrushes and cattails in areas with more permanent water, and spike rush in areas where water was less permanent. In the majority of cases, modified wetlands still largely function as wetlands.

Mid-scale vegetation indicates that Wetland Cienega has about 100% herbaceous vegetation, about 2% shrubs and rest is a mix of tree species and is moderately departed from reference conditions due to increases in late successional vegetation. Vegetation tends to be short because of concentrated use by livestock and wildlife unless access to water is restricted by water depth, fencing, timing of use, or other means. About 40% of wetlands are fenced from cattle or have restrictions regarding the timing of cattle use. None are fenced from wildlife.

Wetland Cienega PNVT is impacted by disturbances in adjacent upland grasslands. The small bodies of water are strongly influenced by snow, water and runoff. Wetland vegetation production is significantly curtailed during drought and likewise increases during wet periods.

This PNVT is rated low for relative departure from reference conditions for weeds. Wetland Cienega has one low ranked weed, Himalayan blackberry, and the populations are few in number with low acreage.

Projected Future Condition and Trend: There is no projected trend for vegetation structure and composition because there is no vegetation model due to its small extent. The projected trend for weeds is to trend away from reference conditions. The presence of Himalayan blackberry is a

relict of past homesteading near this PNVT. Control of Himalayan blackberry is difficult because its fruits are spread by humans and wildlife; and the species reproduces vegetatively.

Comparison of Reference, Current, and Projected Future Conditions and Trends: The number of wetlands across the Forest is reduced from historic levels because some have been converted to reservoirs. Most wetlands have been modified by the construction of dams and stock tanks which has prolonged the permanency of the water within the basins and changed the sizes and shapes of the wetlands. This is not likely to change in the future. Wetland vegetation species composition has likely adjusted to alterations in depth and persistence of water. Vegetation structure height is modified as a result of herbivory on the majority of the wetlands by wildlife and on about 60% of the wetlands by cattle. Use by cattle will be reduced in the future on wetlands that are still scheduled to be fenced. Use by wildlife is expected to continue.

Ponderosa Pine

This widespread PNVT occurs from 5,300 to 8,200 feet in elevation on a variety of parent soils with good aeration and drainage. The dominant species is ponderosa pine. Other trees may be present including: Gambel oak, Douglas-fir, Piñon pine, Utah, Rocky Mountain and alligator juniper. Aspen occurs in small localized areas. This PNVT can have a shrubby understory mixed with grasses including Arizona fescue, mountain muhly, screw leaf muhly, mutton bluegrass, blue grama, bottlebrush squirreltail, and elk sedge. Shrubs may include manzanita and Fendler's ceanothus. Sometimes this PNVT occurs as savannah with extensive grasslands interspersed between widely spaced clumps or individual trees (USDA Forest Service 1995, Vander-Lee et al 2006).

Reference Condition: Under reference conditions, this PNVT supported more open all-aged forests, with a significant herbaceous understory. Early successional and subdominant species such as Gambel oak and aspen of varying age classes were assumed to be distributed in appropriate habitats and regenerating successfully. Table 15 displays the reference conditions for Ponderosa Pine.

Ponderosa pine is a fire adapted system and formerly experienced widespread, low-intensity surface fires with frequent return intervals (Cooper 1960, Covington and Moore 1994, Swetnam and Baisan 1996) however the frequency of fire return intervals reported in the literature varies (see Smith 2006a). For example, in a study of 53 sites in Arizona and New Mexico, Swetnam and Baisan (1996) reported average return intervals of 2-17 years, and 4-36 years depending on age of trees and number of trees with at least one fire scar. In a subset of the same sites, they found fire return intervals to average 15.6 years (range of 5.4 to 36.3 years). Fule and others (2003) found fire frequency to range from 3.0 to 8.9 years in their ponderosa pine fire scar study on the north and south rims of Grand Canyon National Park. Frequency varied by size and location of the fires. Fule and others (2003) reported that historic and current fires burn with a mosaic of intensities and include unburned areas within the fire perimeter. LANDFIRE reports that the normal fire regime for Ponderosa Pine is generally considered to be a fire return interval of <35 years with fire severity typically replacing less than 75% of the overstory.

Ponderosa pine is attacked and killed by several different bark beetles, defoliators, and dwarf mistletoe. Early reports indicate that bark beetle activity was less frequent, extensive, and

damaging in the southwest than other western regions. Insects and disease were assumed to be present at background levels in reference conditions. This includes periodic outbreaks, especially with droughts, or in the absence of controlling disturbance agents. There were significant outbreaks on the Forest in the mid 1920-s, late 1930s, mid-1960s, late 1970s through the early 1980s, and late 1990's through the mid-2000s (Lynch et al 2008).

No invasive and/or noxious weeds were present under reference conditions.

Table 15: Reference and current vegetation conditions of the Ponderosa Pine PNVT[11]

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A, J	Grass Seedling Sapling COMBINED WITH Uncharacteristic Grassland	0	4	0	
B	Young Forest, <30% Cover	0	3	0	
C	Mid-Age Forest, <30% Cover	0	8	0	
D,E	All aged Forest: Mature/Old Forest w/ Regeneration, <30% Cover	100	1	1	
F	Seedling Sapling, >10% Cover	0	0	0	
G	Young Forest, >30% Cover	0	14	0	
H	Young to mid-Age Forest, >30% Cover	0	62	0	
I	Ponderosa Pine Mature/Old Forest w/ Regeneration, >30% Cover	0	8	0	
		100	100	1	99%

Current Condition: Ponderosa Pine currently covers 48% (807,424 acres) of the Forest. This PNVT is less widespread now compared to reference conditions because land ownership shifted to private, and State and other Federal entities. **Much of the private land has been developed.** The current condition was derived using the mid-scale data inventory, which indicates a significant shift from open, all-aged forest to closed, medium-aged forest with a loss of herbaceous understory and tree age diversity which is away from reference conditions. Table 15 displays the current structure for Ponderosa Pine PNVT.

Bark beetles and dwarf mistletoe are persistent in the Ponderosa Pine PNVT. During the 2001-2004 ponderosa pine mortality event, bark beetles (*Dendroctonus* and *Ips* species) impacted 70,000 acres, while dwarf mistletoe impacted an estimated 200,000 acres. Twenty-five percent of the ponderosa pine across the Forest was killed. Fir engravers (an insect) emerged as a significant damage agent in the late 1970s. Incidence and infection severity of dwarf mistletoe has increased over time due to altered disturbance regimes. These changes appear to be in

[11] Although Gambel oak is a widespread species, neither Gambel oak nor aspen are included in the vegetation models for ponderosa pine because Gambel oak is not a dominant species and aspen occurs at too small of a scale for the models. However, Gambel oaks are showing reduced growth because they are being out-competed by ponderosa pine. Aspen is declining due to drought, insects, shading due to conifers and herbivory by elk.

response to changes in forest structure and composition resulting from fire exclusion and past management practices e.g. *Ips* responding to an abundance of dense, small-diameter ponderosa pine and the true fir engraver responding to a proliferation of white fir in ponderosa pine and mixed-conifer forests (Lynch et al 2008).

This PNVT is highly departed from reference conditions for non-native invasive plants because many invasive plant species infest thousands of acres that are dispersed throughout the PNVT. These compete with native plants and populate the seed bank with non-native seeds. Leafy spurge and three knapweed species occur in the PNVT and are very invasive.

Aspen occurs in small patches in Ponderosa pine, mainly in mesic areas or north facing slopes. Aspen communities in the southwest have been declining for decades. This decline is attributable to altered fire regimes since European settlement and heavy browsing by ungulates. This decline accelerated on the Coconino starting in about 1999 after a severe June frost. This frost, combined with fires, insect defoliators, drought and the inability of aspen regeneration to survive browsing has resulted in conversion of aspen to coniferous forest. About 7,000 acres of aspen has been lost in Ponderosa Pine and Dry Mixed Conifer PNVTs below 8,500 feet in elevation in the last 20 years (Lynch et al. 2008).

Projected Future Condition and Trends: Under current management, Ponderosa Pine is expected to remain close to current condition because prescribed burning and vegetative treatments are not occurring at fast enough rates to alter overstory structure. Aspen is expected to be lost from the landscape.

As a result of past and ongoing mechanical treatments and prescribed burning, this PNVT is trending away from reference conditions, but more slowly than other high fire frequency PNVTs.

The degree of mistletoe infestation is assumed to be commensurate with the degree that overstocked stands (canopy > 30%) are present in the landscape (currently about 88%). The trend for insect and disease is expected to be static because the current rate of prescribed burning and vegetative treatments is too slow to open the canopy across a large part of the landscape.

This PNVT is projected to trend away from reference conditions for invasive and/or noxious weeds. Weeds are expected to increase because:

- the opportunity for spread and colonization of new sites is high due to the presence of weeds near recreation sites;
- there are numerous high use roads with numerous weed infestations (Roché and Roché 1999, Gelbard and Belnap 2003, USDA Forest Service 2008);
- many years of treatment are required to control and eradicate leafy spurge;
- there is currently a lack of native understory competition due to high tree densities;
- due to the lack of regenerative fire, the seed bank is now populated with non-native and native seeds; and
- some invasive plants are expected to respond very favorably to the disturbance factor of severe fire when it occurs.

Comparison of Reference, Current, and Projected Future Conditions and Trends: As a result of past and ongoing mechanical treatments and prescribed burning, this PNVT is trending away from reference conditions more slowly than other high fire frequency PNVTs. The current structure makes Ponderosa Pine vulnerable to stand replacing fire, widespread insect and disease infestation, and widespread infestation by invasive and/or noxious weeds. Lack of fire perpetuates the decline of aspen and other fire dependent species and the lack of understory in areas of high canopy closure.

Montane Willow Riparian Forest

Montane Willow Riparian Forest is located mainly from 5,500 to 7,800 feet in elevation along perennial and seasonally intermittent streams, seeps and isolated springs at higher elevations. Trees include Bebbs willow, narrowleaf cottonwood, Arizona walnut, velvet ash, cherry and Arizona alder and dominant shrubs include red osier dogwood, willows, and woods rose (USDA Forest Service 1995).

Reference Condition: Historically, this PNVT was dominated by riparian dependent shrubs at varying canopy closures, with about 35% of the PNVT supporting significant shrub or tree cover (Table 16). The water table was shallow enough to support riparian dependent vegetation. No invasive and/or noxious weeds were present under reference conditions.

Table 16: Reference and current vegetation conditions for Montane Willow Riparian Forest PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early seral shrubs - open canopy	65	1	1	
B	All size classes shrubs, some trees, significant canopy	35	99	35	
		100	100	36	64%

Current Condition:

Montane Willow Riparian Forest covers less than 1% (556 acres) of the Forest. Mid-scale vegetation analysis indicates this PNVT is more dominated now by tree species than in the past. In fact, analysis shows only 147 acres of deciduous trees with the remaining acres overtopped by conifers. It is moderately departed. LANDFIRE indicates that the fire regime condition class of the bulk of this PNVT on the forest is highly departed. Age class diversity and abundance of willows has also decreased (Goodwin 2005, 2006, 2007). The shift in tree species and density likely reduces the amount of water available to support riparian species.

Montane Willow Riparian Forest has few weed species, but some rank high for invasiveness. The non-native orchard grass, for example, is very competitive with native species. Overall, this PNVT has low departure from reference conditions for weeds.

Projected Future Condition and Trends: Under current management, conifers are projected to continue to overtop the willows in the future, resulting in a net loss of riparian species and a shift from riparian to conifer dominated structure.

The Forest's very small dataset for Montane Willow Riparian Forest suggests the PNVT may be trending away from reference conditions. Continued lack of fire is likely to lead to larger extents of overstory replacement per fire occurrence with less mosaic burn pattern than the historic fire regime would manifest.

Based on the invasiveness and competitiveness of the weeds present, this PNVT is projected to continue to move away from reference conditions in the future for weeds. The relative small sites of this PNVT are surrounded by adjacent PNVTs with more weeds, so the potential for introduction of weeds from adjacent PNVTs is high.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Encroachment of conifers from adjacent PNVTs have significantly increased the tree cover in what historically was a willow dominated system. This is due to fire suppression in adjacent PNVTs, which is expected to continue and result in a reduction in willows, other riparian vegetation and herbaceous understory. Fire severity, however, is expected to increase commensurate with the increase in conifers. Water tables may also drop with the increase in conifers.

Montane Subalpine Grassland

Montane Subalpine Grassland occurs at elevations ranging from 6,550 to 9,200 feet and small, unmapped patches exist at higher elevations. Elevations higher than about 7,200 feet support more productive subalpine grasslands. Lower elevations support less productive montane meadows. Southwestern white pine, Engelmann spruce, sub-alpine fir, aspen, and bristlecone pine may occur on meadow edges. Dominant grass species can include: bluegrass, oatgrass, mountain muhly, fescues, sedges, western wheatgrass, squirreltail, blue grama, and red threeawn. Other species may include fleabane, asters, bluebells, penstemons, lupines, shooting star, Rocky Mountain iris, and California false hellebore (USDA Forest Service 1995).

Reference Condition: Historically, this PNVT was more widespread prior to shifts in land ownership to private, State and other Federal agencies. The historic Montane Subalpine Grassland model indicates the landscape was dominated by grass (States B/C) (Table 17).

Table 17: Reference and current vegetation conditions for Montane Subalpine Grassland PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early development, open canopy (herbaceous vegetation)	20	0	0	
B/C	Mid development, open canopy (herbaceous vegetation)	80	67	67	
D	Late development, closed canopy (trees, shrubs & herbaceous vegetation)	0	33	0	
		100	100	67	33%

The normal fire regime for Montane Subalpine Grassland is generally considered to be a fire return interval of <35 years with fire severity typically replacing less than 75% of the overstory. Fires typically entered the PNVT from adjoining PNVTs. The historic grassland did not have any stocktanks. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Montane Subalpine Grassland covers 1.3% (24,199 acres) of the Forest. Current conditions from mid-scale vegetation indicate a significant shift from grass to trees. This reduces the size of and connectivity of grasslands and reduces understory abundance and vigor. This PNVT is moderately departed from reference conditions for vegetation structure and composition. The higher subalpine elevation portion of the PNVT is more productive than lower elevation montane portions due to differences in moisture and history of grazing and vehicle disturbances.

The current fire frequency is far below the historic range of variability and is trending away from reference conditions; probably due to lack of fire spreading from adjacent PNVTs. Fire reduces the number of tree seedling and saplings that establish in grasslands, especially on perimeters. LANDFIRE indicates that 23% of the PNVT is FRCC 2 and 72 % is FRCC 3. While the mid-scale analysis indicates this PNVT is moderately departed, lack of fire from adjoining PNVTs has caused the FRCC to be highly departed.

Stock tanks have been constructed within or near most individual grasslands. Wildlife and livestock concentrate around water resulting in localized shifts towards grazing tolerant species, reduction in vegetation height, soil compaction and disturbance, and shifts in abundance, density and vigor of species.

Montane Subalpine Grassland has a large departure from reference conditions for weeds because while there are few species, some rank high for invasiveness. Less than 1% of this PNVT has leafy spurge populations, but many years of treatments would be necessary to control this species. Leafy spurge spreads rapidly; has toxic effects to livestock, humans and wildlife; and has caused significant economic losses elsewhere in the West (USDA Forest Service 2005).

Projected Future Condition and Trend: The projected future trend for vegetation structure and composition is static due to lack of fire from the adjacent PNVTs moving into this vegetation type. This PNVTs fire regime expects a high percentage of overstory replacement. A continued lack of fire would allow the intrusion of shrubs and trees.

Under current management, the projected trend for weeds is away from reference conditions because of the competitive nature of the weed species, difficulty of controlling weed species, and because they can spread via wind and water, as well as by human and animal vectors.

Comparison of Reference, Current, and Projected Future Conditions and Trends: This PNVT was more widespread historically. Encroachment of conifers from adjacent PNVTs have increased the tree cover in what historically was a grass dominated system. This is due to fire suppression in adjacent PNVTs and is expected to continue. The current shift from native to nonnative species in some areas is expected to continue in the future due to the invasiveness of the weed species, difficulty of control, and likelihood of spread. The impact to the surrounding grassland from the presence of stock tanks is expected to persist in the future.

Dry Mixed Conifer

Dry Mixed Conifer is found at elevations between 7,000 and 8,900 feet between ponderosa pine and spruce fir/sub-alpine conifer forests. The main species in lower and drier elevations are

ponderosa pine mixed with Gambel oak and white fir along with scattered patches of big tooth maple and aspen located in draws. At higher, wetter areas, the main species include Douglas-fir, white fir, limber pine, ponderosa pine, and aspen (Brown 1982). A portion of this wetter condition is found on the San Francisco Peaks; however, the majority is considered to be Mixed Conifer with frequent fire or Dry Mixed Conifer. Other vegetation that may be present, but not co-dominate, include Engelmann spruce at the highest elevations and Colorado blue spruce in select areas including West Fork of Oak Creek. In some areas including Sycamore Canyon, this PNVT can be dominated by Douglas fir or white fir with evergreen oak species (USDA Forest Service 1995).

Reference Condition: At higher elevations and more mesic areas, this PNVT transitioned with Spruce fir, while in lower drier sites, it intergraded with ponderosa pine. It was dominated by mature and old trees with younger age classes of trees in a largely open (<30%) landscape (Table 18). All age classes and significant herbaceous understory were also present.

Table 18: Reference and current vegetation conditions for Dry Mixed Conifer PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A,J	Early development – grass-forb, seedling and sapling w/ aspen or oak Ramets; uncharacteristic grassland (perpetual)	0	2	0	
B	Young Forest, open canopy	0	8	0	
C	Mid-Age forest - open canopy	0	0	0	
D,E	Mature to old forest w/ regeneration – open canopy	100	1	1	
F	Seedling sapling, >10% cover	0	0	0	
G	Young forest – closed canopy	0	78	0	
H	Mid-Age Forest – closed canopy	0	10	0	
I	Mature to old forest w/ regeneration, closed canopy	0	0	0	
		100	100	1	99%

The normal fire regime for Dry Mixed Conifer is generally considered to be a fire return interval of <35 years with fire severity typically replacing more than 75% of the overstory. This maintained the openness of stands and appropriate conditions for the maintenance of early succession species and made them less susceptible to insect and disease. Insects and diseases were present at background levels. No invasive and/or noxious weeds were present under reference conditions.

The vegetation model does not include aspen or maple because they occur at too small a scale. Maple, however, is generally found in wetter sites and in canyons and draws. Aspen was regenerating successfully in areas where it naturally occurred.

Current Condition: Dry Mixed Conifer covers 4.3% (79,060 acres) of the Forest. Because the majority of the dry mixed conifer on the Forest is in lower and drier sites, the frequent fire

regime model (similar to the model for Ponderosa Pine) was used. This PNVT is highly departed from reference conditions because the landscape was historically dominated by open mature/old forest. Analysis of mid-scale vegetation data indicates a significant shift to closed middle-aged forest with a loss of ponderosa pine, herbaceous understory and tree age diversity. Shade tolerant species, such as white fir, are increasing in the understory.

The current fire frequency is far below the historic range of variability and is trending away. This is probably due to fire exclusion in this, as well as adjacent PNVTs. LANDFIRE indicates that 95 % of this PNVT on the forest is in FRCC 3. Consequently, tree density is high in some places and conditions for early succession species are not maintained or created.

The most significant insect and disease damage on the Forest is caused by Douglas-fir beetle, western spruce budworm and fir engraver. Douglas-fir mortality is influenced by drought. During the 2000-2004 drought, there was a strong pattern of Douglas-fir beetle attacks focused on large trees heavily infected with Douglas-fir dwarf mistletoe and possibly root disease. Douglas-fir dwarf mistletoe is believed to be more widespread than southwestern dwarf mistletoe in ponderosa pine. Mistletoe infestation makes the trees more susceptible to mortality from bark beetle attacks. Douglas-fir dwarf mistletoe is thought to be more widespread now than in reference conditions due to the exclusion of fire. Its spread is facilitated by multi-layered dense stand structure. It causes reduced growth and vigor and can eventually result in mortality. Insects can affect different age classes differently depending on the agent and stand structure. Compared to reference conditions, this level of insect and disease is outside the historic range of variability because of the increased amount of dense multi-layered stands and lack of fire.

The Dry Mixed Conifer PNVT has few weed species. Although some rank high for invasiveness, this PNVT has a low departure from reference conditions.

Aspen is distributed throughout this PNVT. Aspen communities in the southwest have been declining for decades. This decline is attributable to altered fire regimes since European settlement and heavy browsing by ungulates. This decline accelerated on the Coconino starting in about 1999 after a severe June frost. This frost, combined with fires, insect defoliators, drought and the inability of aspen regeneration to survive browsing has resulted in the transition of aspen to coniferous forest. Aspen mortality on sites affected by this combination of factors has been estimated as moderate (52%) for elevations between 7,500 and 8,500 feet on the Coconino (Lynch et al. 2008).

Projected Future Condition and Trend: Under current management, vegetation structure and composition is projected to trend towards dense, multi-layered stands, and shift towards shade tolerant species in the future because of insufficient disturbance to restore Dry Mixed Conifer to reference conditions. Aspen is anticipated to transition to coniferous forest. Forest fire occurrence records indicate that current fire severity is within, but may be trending to the upper end of its historic range of variability. While the Dry Mixed Conifer fire regime can experience a high percentage of overstory replacement, continued lack of fire is likely to lead to larger extents of overstory replacement per fire occurrence with less mosaic burn pattern than under the historic fire regime.

Under current management, it is projected that insect and disease infestations will continue to spread in dense portions of this PNVT. White pine blister rust is likely to establish on the Coconino. This exotic pathogen kills white pines and has been found on the Gila, Lincoln, and Santa Fe National Forests in New Mexico. Once established, damage to limber pine is likely to be severe over decades (Lynch et al 2008).

The projected trend for noxious or invasive weeds is away from reference conditions. A portion of this PNVT is within Wilderness, making weed treatment options more difficult.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Nearly 80% of the PNVT is denser, with higher canopy closure, than in reference conditions. Consequently, late successional, shade tolerant species are more prevalent and early successional species are less prevalent. There is less understory vegetation. The risk of uncharacteristic fire that is larger in extent and possibly more severe is higher than reference conditions. Mortality due to insect and disease is likely to continue because of the high proportion of dense stands, lack of fire and the possible introduction of White pine blister rust.

Spruce Fir

The Spruce Fir PNVT ranges from 8,200 -11,850 feet in elevation and is located mainly on the San Francisco Peaks. These sub-alpine conifer forests are dominated by Engelmann spruce, sub-alpine fir or cork bark fir. Douglas-fir with mixed conifer, quaking aspen and bristlecone pine may be present in this system for long periods without regeneration (USDA Forest Service 1995).

Reference Condition: Historically, Spruce Fir was comprised of a variety of age classes and canopy cover (Table 19).

Table 19: Reference and current vegetation conditions for Spruce Fir PNVT

State	Successional Structure, Composition & Cover Class	Reference Percent	Current Percent	Similarity Value	Departure Value
A	Early development; grass/forb seedling/sapling w/ aspen ramets	25	5	5	
B	Mid development; young to mid-aged forest with regeneration	35	90	35	
C	Late development; mature old forest with regeneration	40	5	5	
		100	100	45	55%

Reference conditions for insects and disease are unknown, but it is assumed that native insects and disease were present at background levels. No invasive and/or noxious weeds were present under reference conditions. Spruce-fir had infrequent high severity fires.

Current Condition: Spruce Fir covers less than 1% (13,942 acres) of the Forest. Current extent is similar to extent that occurred under reference conditions. Currently there are a surplus of younger age classes and fewer older age classes due to the extensive wildfires in the PNVT that occurred in the early 1900s. There is less area occupied by seedlings, saplings and aspen regeneration. The frequency of high severity fires is within the HRV, according to Forest fire

occurrence records. LANDFIRE indicates that 52% of the fire regime condition class for this PNVT on the forest is moderately departed, and 48% is highly departed. Even though this PNVT has departures in both vegetation and fire regime condition class, both departures are considered within the HRV because the PNVT has a fire return interval of over 200 years.

Currently, 340 acres are affected by Spruce beetle. There are an unknown number of acres affected by true fir beetles. Although reference conditions are unknown, this is considered to be within the historic range of variability because a small number of acres are affected, and insects and disease are thought to be at natural background levels for the PNVT.
There are an unknown number of acres affected by the exotic spruce aphid which damages Engelmann spruce and Colorado blue spruce of all size classes. In the White Mountains of Arizona, spruce aphids have killed 25-40% of severely damaged Engelmann spruce after a single defoliation episode. Also, the likelihood of mortality after spruce aphid feeding is increased by the severity of the pre-existing spruce dwarf mistletoe infection (Lynch et al 2008).

The Spruce Fir PNVT has two low ranked species of weeds (Dalmatian toadflax and houndstongue) and the populations are few in number and acreage. Because of the ranking, and size and number of infestations, this PNVT has low departure from reference conditions for noxious weeds.

Projected Future Condition and Trend: VDDT modeling predicts that Spruce Fir is moving towards reference conditions under current management. While one of this PNVT‘s fire regimes expects a high percentage of overstory replacement, continued lack of fire is likely to lead to larger extents of overstory replacement per fire occurrence than would occur if the other frequent low severity fire regime with a more mosaic burn pattern were on schedule.

The Spruce Fir PNVT is located in wilderness on the San Francisco Peaks where there is little active management. A general decline of Engelmann spruce is possible if the exotic spruce aphid persists in the ecosystem, such as has been seen in the White Mountains. The response of Spruce Fir to climate change is uncertain because of the uncertainty associated with climate change. If localized warmer, drier conditions persist over time, this cold tolerant, moisture dependent PNVT could have pronounced shifts in composition and structure due to mortality and stress. Insect and disease impacts could increase. This PNVT is vulnerable because it is found mainly in only one location on the Forest and under severe circumstances, could potentially be lost from the Forest.

White pine blister rust is likely to establish on the Coconino according to Lynch et al (2008). Damage to bristlecone pines from this exotic pathogen is likely to be severe over several decades once it becomes established.

The projected trend for weeds is away from reference conditions, however, because increased recreation over time may provide vectors for introduction of species, and the PNVT‘s presence in wilderness makes control options more limited.

Comparison of Reference, Current, and Projected Future Conditions and Trends: There has been a shift in age class distribution in the Spruce Fir PNVT in response to large wildfires in the early 1900‘s. Vegetation, fire return interval, and fire severity appear to be largely functioning within

the historic range of variability. The presence of weeds and the exotic spruce aphid are outside the HRV. Diminished presence of Engelmann spruce is a likely consequence of the spruce aphid, and weed infestation is slow due to high elevation and local weather patterns.

Alpine Tundra

Alpine Tundra on the Coconino National Forest begins around 10,600 feet in elevation and continues to the top of Humphrey‘s Peak, the highest point in Arizona. This PNVT is typically barren with sparse vegetation including grasses, forbs, lichens and low shrubs. Dominant forbs include avens and sandwort. Alpine Tundra is made of three species associations: meadows, talus slopes and boulder fields.

Reference Condition: Past extent of Alpine Tundra is assumed to be similar to present. Meadow, talus slope and boulder field speices were present at normal background levels. Weather related factors are the major disturbance processes and include extreme temperatures, solar radiation, winds, avalanches, and moisture. No invasive and/or noxious weeds were present under reference conditions.

Current Condition: Alpine Tundra covers less than 1% (941 acres) of the Forest. This is one of the few locations of Alpine Tundra on National Forest lands in the Southwestern Region and one of the most southern extents of alpine tundra in the Continental United States. It is moving away from reference conditions because the trend is towards increased meadow species and fewer talus slope species apparently due to changes in weather patterns. Fire is not an ecological determinant for this PNVT.

The Alpine Tundra PNVT has no weeds at the current time and, thus, has low departure from reference conditions.

Projected Future Condition and Trend: The response of Alpine Tundra to shifts in weather patterns is uncertain. If localized warmer, drier conditions persist over time, this high elevation dependent PNVT could have pronounced shifts in composition and structure due to plant mortality, stress, or more shifts to meadow species.

Establishment of weeds is not expected in the future. The harsh environment of Alpine Tundra and its remoteness from roads and management activities of the Forest tend to make this PNVT less subject to invasions of weeds. However, increased recreation over time may provide vectors for introduction of species, and the PNVT‘s location in the Kachina Peaks Wilderness makes control options more limited.

Comparison of Reference, Current, and Projected Future Conditions and Trends: Departure is assumed to be within the historic range of variability. Changes in weather patterns are causing a shift in species composition. Alpine Tundra is vulnerable because it is found in only one location on the Forest and in the Southwestern Region of the Forest Service. In the worst case scenario, it could potentially be lost from the Forest and Region.

Forest FRCC Departures

The fire regime condition classes for the majority of Forest acres are either moderately departed (FRCC 2) (32% of acres) or highly departed (FRCC 3) (60% of acres) from reference conditions according to LANDFIRE National Assessment (USDA Forest Service 2009). Information in Table 20 shows that for the three PNVTs with the largest extents on the Forest:

- 87% of Ponderosa Pine is in FRCC 3,
- 72% of Piñon Juniper Woodland is in FRCC 3, and
- 86% of Piñon Juniper Evergreen Shrub is in FRCC 2.

The last column in the table qualitatively describes the degree of departure based on the percent of acres in each FRCC. Changes in vegetative structure within PNVTs have changed fuel conditions, so there is an increased risk of severe fires. Of the acres that have burned since 1988, one third has not burned with the fire severity appropriate to its PNVT. Fire, however, is not considered a major historical ecological process in the following PNVTs: Cottonwood Willow Riparian Forest, Desert Communities, Mixed Broadleaf Deciduous Forest, Wetland Cienega, Montane Willow Riparian Forest, and Alpine Tundra.

Table 20: Fire regime condition class by percent for PNVTs on Coconino NF

	PNVT Acres on Coconino NF*	Fire Regime Condition Class 1	Fire Regime Condition Class 2	Fire Regime Condition Class 3	Departure From Reference Condition
PNVTs > 1% extent of Forest		% in:	% in:	% in:	
Semi-Desert Grassland	147,573	10%	80%	10%	High**
Great Basin Grassland	94,277	22%	22%	56%	High
Interior Chaparral	50,687	40%	39%	21%	Moderate
Piñon-Juniper Evergreen Shrub	300,154	9%	86%	4%	Moderate
Piñon-Juniper Woodland	301,675	4%	24%	72%	High
Ponderosa Pine	807,424	4%	9%	87%	High
Dry Mixed Conifer	79,060	2%	3%	95%	High
Montane / Subalpine Grassland	24,199	4%	23%	72%	High
PNVTs < 1% of Forest					
Cottonwood Willow Riparian Forest	2,017	Not a fire adapted system			
Mixed Broadleaf Deciduous Riparian Forest	2,562	Not a fire adapted system			
Wetland Cienega	1,140	Not a fire adapted system			
Montane Willow Riparian Forest	557	6%	15%	79%	High
Desert Communities	6,339	Not a fire adapted system			
Spruce fir	13,942	0%	52%	48%	Moderate
Alpine Tundra	941	Not a fire adapted system			

*Acres do not sum to Forest total because categories of Urban/Agriculture, Disturbed/Altered, and Water are not displayed.
** When LANDFIRE data is considered along with Forest fire frequency records and mid-scale vegetation data, semi-desert grassland FRCC departure from reference is considered high (USDA Forest Service 2009).

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Some of the qualitative fire regime condition class departures in Table 20 are different than the vegetative departures described earlier (such as with Interior Chaparral and Piñon Juniper Woodland) because FRCC is heavily influenced by current fire frequency and potential fire severity. FRCC departures are focused on differences in fuel conditions as they relate to ecosystem process and function. Vegetative departures are focused on differences in vegetative states as they relate to ecosystem composition and structure.

Information in Table 21 shows wildfire is burning far fewer acres by PNVT now than it did historically. All of the PNVTs are outside their historical fire return interval except for the non-fire adapted ecosystems identified in Table 20.

Table 21: Comparison of wildfire extent, frequency, and severity by PNVT[12].

	PNVT Acres on Coconino N.F.	Current Yearly Average Wildfire Acres Burned	Expected Yearly Average W/in HRV	Current Fire Return Interval in Years	Historic Fire Return Interval in Years	Current % of Dominant Overstory Replacement	Historic % of Dominant Overstory Replacement	Fire Severity within, higher or lower than HRV?	Fire Frequency within HRV?
PNVTs > 1% extent of Forest									
Semi-Desert Grassland	147,573	52	8,199	2,500	1 - 35	78%	0-74%	Higher	No
Great Basin Grassland	94,277	50	5,238	2,000	1 - 35	80%	>75%	Within	No
Interior Chaparral	50,687	134	745	384	20 - 200	58%	>75%	Lower	No
Piñon-Juniper Evergreen Shrub	300,154	183	2,543	1,667	35 - 200+	48%	0-74%	Within	No
Piñon-Juniper Woodland	301,675	1,651	2,557	192	35 - 200+	77%	0-74%	Higher	Yes
Ponderosa Pine	807,424	2,278	44,857	344	1 - 35	62%	0-74%	Within	No
Dry Mixed Conifer	79,060	606	4,392	130	1 - 35	62%	>75%	Lower	No
Montane / Subalpine Grassland	24,199	42	1,334	588	1 - 35	60%	0-74%	Within	No
PNVTs < 1% of Forest									
Cottonwood Willow Riparian	2,017	1	17	2,000	35 - 200+	55%	>75%	Lower	Yes
Mixed Broadleaf Deciduous	2,562	0	22	2,000	35 - 200+	50%	>75%	Lower	Yes

[12] Acres do not add up to Forest total because Urban Agricultural, Disturbed Altered, and Water are not included.

	PNVT Acres on Coconino N.F.	Current Yearly Average Wildfire Acres Burned	Expected Yearly Average W/in HRV	Current Fire Return Interval in Years	Historic Fire Return Interval in Years	Current % of Dominant Overstory Replacement	Historic % of Dominant Overstory Replacement	Fire Severity within, higher or lower than HRV?	Fire Frequency within HRV?
Riparian									
Wetland Cienega	1,140	0	10	2,000	35 - 200+	*	>75%	*	Yes
Montane Willow Riparian Forest	557	2	5	278	35-200+	50%	>75%	Lower	Yes
Desert Communities	6,339	3	32	2,000	200+	81%	>75%	Within	*
Spruce fir	13,942	17	118	833	35 -200 & 200+	51%	0-74% & >75%	*	*
Alpine Tundra	941	0	5	200+	200+	*	>75%	*	*
* Forest data insufficient to determine.									

Eighty-three percent of the Forest acreage has not been burning with a frequency appropriate to the fire regime for its PNVT. For example, at the current wildfire frequency, it would take 345 years for each acre of Ponderosa Pine to move through one fire cycle, when it should take a maximum of 35 years. When prescribed burning is considered, it would take 66 years to move through one fire cycle, which is still longer than the historic fire frequency (USDA Forest Service 2009). Nearly all of the Forest's prescribed burning occurs in the Ponderosa Pine PNVT.

Temporal niche summary

Temporal niche analysis (i.e. comparison of reference to current conditions) demonstrated that composition and structural shifts away from reference conditions have occurred in most of the Coconino's PNVTs, except for Alpine Tundra. The primary changes are reduced vegetation age diversity, shifts in canopy cover, and widespread reduction in herbaceous understory. Although Alpine Tundra has a low departure, there is a projected trend away from reference conditions if there are extended periods of localized warming or drying trends (Schaak 1970).

For forest vegetation, dense vegetative states will persist into the future, assuming current disturbance patterns continue. This trend results in a shift away from all age classes being represented to an emphasis on medium diameter trees, except in Spruce Fir which is trending towards older trees. There is also a loss of ponderosa pine and aspen in the Dry Mixed Conifer PNVT, as well as a loss of aspen in the Ponderosa Pine PNVT.

For woodland vegetation, there has been a shift to denser vegetation in Piñon Juniper Evergreen Shrub, and a loss of tree age diversity in Piñon Juniper Woodland.

The trends in grassland vegetation are increases in shrubs and trees and the trends in riparian vegetation are loss of tree age diversity, shifts to later succession vegetation and changes in

canopy cover. In Mixed Broadleaf Deciduous Riparian and Montane Willow Riparian, there is a shift towards more conifers.

Vegetative departures are corroborated by the separate analysis of fire regime condition class. Similar to the findings of the Forest PNVT analysis, the majority of PNVT acres on the Forest have moderate to high departures in FRCC. Contributing factors to these departures are the structural shifts to denser forests and woodlands, higher canopy cover, and increasing woody vegetation in grasslands and desert ecosystems, all of which can contribute to changes to higher FRCC rankings. Widespread reduction in herbaceous understory can also contribute to missed fire cycles and higher FRCC rankings because understory carried fire in the historical landscape. Existing vegetative trends in most PNVTs increase their vulnerability to fire severity outside their HRV.

SPATIAL NICHE ANALYSIS

The importance of lands within the Coconino NF to the sustainability of ecosystems within larger ecological sections depends on the amount and condition within and outside the Forest's boundary. The spatial niche analysis is intended to place the Forest into a broader ecological context and focuses on the distribution of ecological communities within and outside the Forest boundaries.

Table 22 shows the relationship or scale, in acres, of PNVTs on the Coconino to ecoregion sections. The third column is the percentage of the PNVT on the Forest. The fourth, fifth and sixth columns display the percentages of the Coconino's PNVTs in the sections.

Table 22: PNVT percentage on the Forest and spatial contribution to sections

Coconino contribution to PNVT total area within sections					
Major PNVTs > 1% of Forest	**Forest Acres***	**% of Forest**	**% in 313C**	**% in 313D**	**% in M313A**
Semi-Desert Grasslands	147,573	8	7	0	<1%
Great Basin Grasslands	94,277	5.1	<0.1%	0.3	4
Interior Chaparral	50,687	2.8	1	0	15
Piñon Juniper Evergreen Shrub	300,154	16.3	30	0	5
Piñon Juniper Woodland	301,675	16.4	0	2	9
Ponderosa Pine	807,424	43.8	9	1	17
Dry Mixed Conifer	79,060	4.3	1	0	10
Montane/Subalpine Grassland	24,199	1.3	98**	0	14

PNVTS/systems <1% of Forest					
Cottonwood Willow	2,017	0.1	18	0	0
Mixed Broadleaf Deciduous	2,562	0.1	15	0	2
Wetland Cienega	1,140	0.1	0	0	6
Montane Willow	557	0.0	0	0	2
Desert Communities	6,339	0.3	1	0	0
Spruce Fir	13,942	0.8	0	0	11
Alpine Tundra	941	0.1	0	0	100

*Acres do not add up to Forest total because Urban/Agriculture, Water, and Disturbed/Altered are not displayed.
** Although it appears as if there is substantive contribution associated with Montane Subalpine Grassland in 313C, this is actually minor because this contribution represents a mapping discrepancy associated with the section boundary delineation at a small scale.

As stated in the Introduction, the Forest's largest contribution to the sustainability of overall vegetative resources is to the White Mountains-San Francisco Peaks-Mogollon Rim section (M313A) with lesser contributions to Sections 313C (Tonto Transition) and 313D (Painted Desert). In support of this, Table 22 shows that the largest Forest contribution is to the sustainability of Alpine Tundra in M313A because 100% of the PNVT is located on the Forest. Forest management of Alpine Tundra makes a significant contribution to the ecological sustainability of this type within the section.

The Coconino has a noticeable spatial contribution of Piñon Juniper Evergreen Shrub (30%) in Section 313C.

The Forest also has small, but still important, spatial contributions to the sustainability of seven PNVTs in two sections - M313A and 313C. In M313A, the Forest contributes 17% of Ponderosa Pine, 15% of Interior Chaparral, 14% of Montane Subalpine Grassland, 11% of Spruce Fir, and 10% of Dry Mixed Conifer. In 313C, the Forest contributes 18% of the Cottonwood Willow Riparian and 15% of Mixed Broadleaf Deciduous Riparian.

The spatial niche analysis emphasizes once again the contributions the Forest makes to the ecological sustainability of Section M313A, the White Mountains-San Francisco Peaks-Mogollon Rim section. Contributions are primarily to the sustainability of Alpine Tundra based on its extent being entirely on the Forest. Secondary contributions (i.e., lesser proportional extent on the Forest) are to the sustainability of Interior Chaparral, Ponderosa Pine, Dry Mixed Conifer, Spruce Fir and Montane Subalpine Grassland in M313A and to the sustainability of Cottonwood Willow Riparian and Mixed Broadleaf Deciduous Forest in Section 313C, the Tonto Transition section.

Summary of Temporal and Spatial Niche Analyses

The first part of the summary consists of three tables that numerically display the extent and departure of PNVTs found on the Forest, by section. Using the information provided in these tables, the next part describes the spatial and temporal niche of each PNVT and the Forest

contribution to the ecological sustainability of that PNVT. The final part summarizes key findings for forest, wood, grassland and riparian ecosystems, fire regime condition class, and invasive or noxious weeds.

Tables 23-25 summarize the proportional extent and departures of PNVTs on and off Forest by section. This displays Forest contributions to ecological sustainability of PNVTs based on considerations of both temporal (current vs. reference conditions) and spatial (PNVT extent on and off Forest) niche analyses. Columns 4-6 show how the PNVTs are proportionally distributed on and off Forest and columns 7-8 show temporal niche information, i.e., departures, on and off Forest.

Table 23: Proportional extent and departures of PNVTs and water in Section M313A

	Total PNVT Forest*	Total PNVT in M313A	M313A On Forest	M313A Off Forest	M313A On Forest	M313A Off Forest	M313A On Forest	M313A Off Forest
PNVT Description	**Acres**	**Acres**	**Acres**	**Acres**	**%**	**%**	**Departure Value**	**Departure Value**
Alpine Tundra	941	941	941	0	100	0	Considered low	Not applicable
Great Basin Grassland	94,277	1,789,899	69,936	1,719,962	4	96	17	59
Interior Chaparral	50,687	233,468	36,006	197,462	15	85	3	16
Mixed Broad Leaf Deciduous Riparian Forest	2,562	19,747	379	19,368	2	98	58	46
Dry Mixed Conifer	79,060	753,072	79,052	674,020	10	90	99	98
Montane Subalpine Grassland	24,199	174,810	23,907	150,903	14	86	33	50
Montane Willow Riparian Forest	557	24,302	531	23,772	2	98	64	36
Piñon Juniper Evergreen Shrub	300,154	622,640	33,189	589,451	5	95	39	68
Piñon Juniper Woodland	301,675	2,913,278	267,151	2,646,127	9	91	45	28
Ponderosa Pine	807,424	4,573,316	774,206	3,799,110	17	83	99	94
Semi-desert Grasslands	147,573	761,965	534	761,431	<1%	100	100	80
Spruce Fir	13,942	128,702	13,942	114,760	11	89	55	42
Wetland/Cienega	1140	18,468	1,140	17,328	6	94	64	36

*Acres do not add up to Forest total because Urban/Agriculture, Water, and Disturbed/Altered are not shown. Cottonwood Willow Riparian Forest and Desert Communities are not in this section.

Table 24: Proportional extent and departures of PNVTs and water in Section 313C

	Total PNVT Forest	Total PNVT in 313C	313C On Forest	313C Off Forest	313C On Forest	313C Off Forest	313C On Forest	313C Off Forest
PNVT/system	**Acres***	**Acres**	**Acres**	**Acres**	**%**	**%**	**Departure Value**	**Departure Value**
Cottonwood Willow Riparian Forest	2,017	11,329	2,017	9,312	18	82	49	32
Desert Communities	6,339	592,719	6,339	586,380	1	99	80	79
Interior Chaparral	50,687	1,433,397	14,681	1,418,716	1	99	3	12
Mixed Broad Leaf Deciduous Riparian Forest	2,562	14,241	2,182	12,059	15	85	44	47
Great Basin Grassland	94,277	33,326	5	33,321		100	Not applicable	
Montane Subalpine Grassland	24,199	298	292	6	98	2	33	20
Piñon Juniper Evergreen Shrub	300,154	881,124	266,965	614,158	30	70	45	61
Piñon Juniper Woodland	301,675	114,202	3	114,199		100	Not applicable	
Ponderosa Pine	807,424	336,710	31,690	305,020	9	91	99	90
Dry Mixed Conifer	79,060	1,336	8	1,328	1	99	Not applicable	
Semi-desert Grasslands	147,573	2,131,047	147,039	1,984,008	7	93	100	90
Montane Willow Riparian Forest	557	19,849	27	19,822	5	95	Not applicable	

*Acres do not add up to Forest total because Urban/Agriculture, Water, and Disturbed/Altered are not shown. The remaining PNVTs on the Forest are not present in this section or are only present in negligible amounts.

Table 25: Proportional extent and departures of PNVTs and water in Section 313D

	Total PNVT Forest	Total PNVT in 313D	313D On Forest	313D Off Forest	313D On Forest	313D Off Forest	313D On Forest	313D Off Forest
PNVT Description	**Acres**	**Acres**	**Acres**	**Acres**	**%**	**%**	**Departure Value**	**Departure Value**
Great Basin Grassland	94,277	6,707,662	24,335	6,683,327	0.3	99.7	60	74
Piñon Juniper Woodland	301,675	1,699,066	34,520	1,664,545	2	98	67	48
Ponderosa Pine	80,7424	136,621	1,527	135,094	1	99	100	87
* Acres do not add up to Forest total because Urban/Agriculture, Water, and Disturbed/Altered are not shown. The remaining PNVTs on the Forest are not present in this section or are only present in negligible amounts.								

Summaries: PNVTs > 1% on Forest

Semidesert Grassland. *Spatial niche*: The majority of Semidesert Grassland on Forest is in Section 313C with 7% on Forest and 93% off Forest. *Temporal niche*: Departure from reference conditions is high on and off Forest. The Forest's overall contribution to ecological sustainability of this PNVT is high because the PNVT is at overall risk of loss of sustainability within the section and is located on lands of varying ownership. Off forest portions of the PNVT may be urbanized. Coconino NF has the opportunity to improve conditions within the PNVT and increase the Forest's conservation burden relative to the rest of the section. In other words, the Forest could improve vegetative conditions so that the portion of the PNVT on the Forest functions as a refugium that supports vegetation less departed from reference than off Forest portions.

Great Basin Grassland. *Spatial niche*: The majority of the PNVT is off Forest in Sections M313A (96%) and 313D (99.7%). On and off Forest portions in Section 313D are more departed than in M313A due to increased juniper presence, and the on Forest departure is less than off Forest departure in both sections. *Temporal niche*: The Forest has an increased conservation burden due to proportionally higher similarity to reference conditions compared to off Forest portions. Thus, the Forest's overall contribution to the sustainability of this PNVT is considered to be high.

Interior Chaparral. *Spatial niche*: The majority of PNVT is found off Forest in Sections M313A (85%) and 313C (99%) with the Forest contributing 15% of the acres in M313A. *Temporal niche*: Departures are low on and off Forest in both sections. Forest contribution to ecological sustainability of the PNVT is moderate because of the proportion of the PNVT in section M313A and the current similarity of the PNVT to reference conditions. The Forest has the opportunity to maintain and improve conditions where possible so departure from reference remains low.

Piñon Juniper Evergreen Shrub. *Spatial niche*: The Forest contributes 30% of the acres in Section 313C and 5% of the acres in M313A. *Temporal niche*: In 313C, departures are moderate on (45%) and off (61%) Forest. Conditions on Forest, however, are more similar to reference

conditions. In M313A, departures are considerably less (39%) on Forest compared to off (68%). Forest contribution to ecological sustainability is high due to the spatial contribution in Section 313C and relatively lower departures compared to off Forest. The on Forest portion of the PNVT in section M313A currently functions as a refugium because on Forest departures are less than those off Forest. The Coconino has the opportunity to improve on Forest conditions in the PNVT.

Piñon Juniper Woodland. *Spatial niche*: The majority of PNVT acres are found off Forest in Sections M313A (91%), 313C (nearly 100%), and 313D (98%). *Temporal niche*: The departure values are higher on Forest (moderate to high) than off Forest (low to moderate). This PNVT is fragmented in some areas, including the Forest. The Forest contribution to ecological sustainability of this PNVT is moderate. The Coconino has the opportunity to move Forest conditions towards reference so that the Forest functions more as a refugium.

Ponderosa Pine. *Spatial niche*: A higher proportion of the PNVT is found off Forest in Sections M313A (83%), 313C (91%), and 313D (99%). The Coconino contributes 17% of the acres in M313A, which contains the highest amount (over 4 million acres) of Ponderosa Pine. *Temporal niche*: Ponderosa Pine is highly departed on and off Forest in all sections, and the Forest has relatively higher departure values than those off Forest. The Forest‘s overall contribution to ecological sustainability of this PNVT is high because the PNVT is at overall risk of loss of sustainability within all sections, vulnerable to wildfire (and potentially large scale loss), and is fragmented in many areas. Portions of the PNVT off Forest are under other ownership, and may be developed. Coconino NF has the opportunity to improve vegetative conditions and increase the Forest‘s conservation burden relative to the off-Forest portions such that the on Forest portion of the PNVT functions as a refugium that supports vegetation that is less departed than off Forest portions of the PNVT.

Dry Mixed Conifer. *Spatial niche*: A higher proportion of the PNVT is found off Forest in Section M313A (90%) with negligible amounts in 313C and 313D. Ten percent of the PNVT acres in M313A are on the Coconino. *Temporal niche*: The Dry mixed conifer PNVT is highly departed on and off Forest. The Forest‘s overall contribution to ecological sustainability of this PNVT is high because the PNVT is at overall risk of loss of sustainability in M313A and is fragmented in some areas. Portions of the PNVT off Forest are under other ownership, and may be developed. Coconino NF has the opportunity to improve vegetative conditions and increase the Forest‘s conservation burden relative to the rest of the section, that is, so that the on Forest portion of the PNVT functions as a refugium that supports vegetation that is less departed than off Forest portions of the PNVT.

Montane Subalpine Grassland. *Spatial niche*: A higher proportion of the PNVT is found off Forest in Section M313A (86%) with negligible amounts in 313C. The Coconino contributes 14% of the acres in M313A. *Temporal niche*: Montane Subalpine Grassland is moderately departed on and off Forest, but the Coconino is more similar to reference conditions (33% departure value) than off Forest (50%). This PNVT is fragmented and portions of it may be developed within the section. Forest contribution to ecological sustainability is moderate due to the relatively lower departure value (higher conservation burden) and proportional extent of the PNVT within this section.

Summaries: PNVTs < 1% on Forest

Cottonwood Willow Riparian. *Spatial niche*: All Cottonwood Willow Riparian on Forest is in Section 313C with 18% on Forest and 82% off. *Temporal niche*: The PNVT's departure from reference condition is moderate both on and off forest. This PNVT has higher risk of loss of sustainability because it is located in only one section and is fragmented in portions of the section, as well as the Forest. The Forest contribution to ecological sustainability is moderate due to the proportional extent on the Forest and departure value. The Forest has the opportunity to improve conditions within the PNVT so that they are more similar to reference.

Mixed Broadleaf Deciduous. *Spatial niche*: Forest contributes 15% of the PNVT in 313C, and the majority is off Forest in M313A (98%). *Temporal niche*: Departures are moderate on and off forest in both sections. The Forest contribution to ecological sustainability is moderate because of the proportional extent on the Forest and the moderate departure from reference conditions. The Forest has the opportunity to improve on Forest conditions so they are more similar to reference.

Wetland Cienega. *Spatial niche*: This entire PNVT is in M313A with 6% on Forest and 94% off Forest. *Temporal niche*: The Forest is more highly departed (64%) than off Forest (36%). Wetland Cienega has a higher risk of loss of sustainability than other PNVTs because it occurs in only one section. The Forest contribution to sustainability is moderate and the Forest has the opportunity to improve conditions within this PNVT.

Montane Willow Riparian. *Spatial niche*: Forest contributes 2% of the PNVT in M313A and 0.1% in 313C. *Temporal niche*: The departure is 64% on Forest compared to 43% off Forest. This small PNVT has a higher risk of sustainability than other PNVTs because it occurs in only one section and is naturally fragmented. Forest contribution to ecological sustainainability of Montane Willow Riparian is moderate. The Coconino has the opportunity to improve conditions within this PNVT.

Desert Communities. *Spatial niche*: The Forest contributes 1.3% of the PNVT in 313C with the remainder being off Forest. *Temporal niche*: The departure on Forest and off Forest is high (80%). This PNVT has a higher risk of loss of sustainability than other PNVTs because it occurs in one section. It is vulnerable in some portions of the PNVT to additional fragmentation due to development and it occurs on lands of varying ownership in the section. The Forest contribution to ecological sustainability is high because this PNVT is at risk of loss of sustainability throughout the section. The Forest has the opportunity to move on Forest PNVT conditions towards reference.

Spruce Fir. *Spatial niche*: The Forest contributes 11% of the PNVT in Section M313A with the remaining 89% off Forest. This PNVT has a higher risk of loss of sustainability than other PNVTs because it occurs in one section, and because it occurs in only one location on the Forest. *Temporal niche*: This PNVT has a 55% departure value on Forest and a 42% departure value off Forest. The Forest contribution to ecological sustainability of this PNVT is high because of the spatial extent on the Forest. The Forest has the opportunity to improve vegetative conditions within the PNVT so they trend towards reference.

Alpine Tundra. *Spatial niche:* All Alpine Tundra on the Forest in Section 313A with 100% on Forest. This PNVT potentially has a high risk of loss of sustainability because it occurs in one section and is located in one area on the Forest. *Temporal niche*: The current condition of this PNVT is considered to similar to reference conditions, although it may trend away from reference conditions if warming or drying trends persist. The Forest contribution to the ecological sustainability of this PNVT is high because all of the alpine tundra in the section is on the Forest.

KEY FINDINGS

Dominant Vegetation

Forests. The Forest contribution to the sustainability of the Ponderosa Pine and Dry Mixed Conifer PNVTs at the section level is high. Conclusions from the above temporal analysis, however, indicate there have been significant shifts from open, all aged forests to closed, medium aged ponderosa pine and mixed conifer forests. Trends towards higher average canopy cover contribute to an overall reduction in herbaceous understory, which would have been the main carrier of fire in a historic fire regime. Fire regime condition class is highly departed for the Ponderosa Pine and Dry mixed conifer PNVTs. Even though the Forest's prescribed burning program has made significant progress in increasing fire frequency in the Ponderosa Pine PNVT, it still is estimated to take 66 years to move through one fire cycle when it should take a maximum of 35 years. Other consequences of having the vegetation structure outside the historic range of variability are: the loss of ponderosa pine in the Dry Mixed Conifer PNVT, lack of conditions that support early seral species such as aspen, maintenance of herbaceous and woody understory, increased vulnerability to uncharacteristic fire, as well as insects and disease outbreaks. Insect and disease in the Dry Mixed Conifer and Ponderosa Pine PNVTs are outside the historic range of variability because of the increased amount of dense and multi-layered stands.

Woodlands. Most of the Piñon Juniper Woodland PNVT has shifted from medium to very large sized trees and an open canopy to small to medium sized trees and a more closed canopy. Likewise, most of the Piñon Juniper Evergreen Shrub PNVT has shifted to a more closed canopy structure with corresponding changes in both PNVTs to species composition, structure and processes. Fire regime condition class for the Piñon Juniper Woodland PNVT is highly departed from reference conditions and fire regime condition class for the Piñon Juniper Evergreen Shrub PNVT is moderately departed. Subsequent loss of herbaceous understory in both PNVTs exacerbates the lack of disturbance (in this case, fire) in these ecoystems. The absence or discontinuous nature of understory results in a spatial shift of fine fuels that carried fire in a historical fire regime. Lack of disturbance, in turn, modifies the shrub and tree age class distribution and increases the potential for severe fires. The vegetation structural trends increase vulnerability to insect and disease outbreaks as evidenced by the recent drought that influenced 150,000 acres of mortality in Piñon Juniper Woodlands on the Forest. The potential for severe fires also increases susceptibility to invasion and establishment of noxious weeds.

Grasslands. Most of Semi-Desert Grassland has been invaded by woody species with subsequent changes in species composition, structure and processes. According to Vander-Lee et al. (2007), about 30 percent of these invaded acres have undergone a type conversion with little potential for restoration to native grassland. Montane Subalpine Grasslands and 17% of the Great Basin

Grassland, primarily in Section 313D, have been invaded by shrubs and trees as well. Semi-Desert Grassland and Great Basin Grassland have few invasive or noxious weed species, but some have high ranks for invasiveness, and nonnative annual grasses such as red brome and cheat grass are widely dispersed at low densities and can cause major changes in ecosystem integrity.

Riparian: Current conditions from mid-scale vegetation indicate a significant shift to smaller trees in Cottonwood Willow Riparian and Mixed Broadleaf Deciduous Riparian. In Cottonwood Willow Riparian there has been a shift away from large trees. In Mixed Broadleaf and Montane Willow Riparian Forests, there has been a shift towards closed canopy which facilitates a trend towards more conifer dominated rather than riparian dominated structure. This increases the vulnerability of these PNVTs to catastrophic fire from adjacent PNVTs. These riparian PNVTs have few invasive or noxious weed species, but some have high ranks for invasiveness, and nonnative annual grasses such as red brome and cheat grass are widely dispersed at low densities and can cause major changes in ecosystem integrity if not controlled.

In Wetland Cienega, mid-scale vegetation analysis indicates a shift towards later succession vegetation compared to reference. Structure height is reduced where accessible by herbivores. All wetlands are accessible to wildlife and 60% are grazed by livestock at some time. Structure and function of wetlands have been modified from historic conditions due to stock tanks, most of which were created prior to the creation of the Forest Plan. There are few invasive or noxious weed species.

Fire Regime Condition Class. The majority of the acreage on the Forest, and the majority of the PNVTs have fire regime condition classes moderately to highly departed from reference conditions. Of the PNVTs where fire played a historic role, all except Piñon Juniper Woodland and Spruce Fir are outside their historical fire return interval. All PNVTs are trending away. One-third of the acres on the Forest have not burned with the severity appropriate for its PNVT since 1988. There is also an increase in the total number of acres burned by wildfire across the Coconino National Forest, particularly in the last 10 years.

Invasive or noxious weeds. For most PNVTs, the current relative departure of invasive or noxious weeds from reference conditions is low to moderate. All of the PNVTs except for Alpine Tundra show trends away from reference conditions for invasive and noxious weeds. There are 24 taxa of serious invasive or noxious weeds infesting the Coconino. There are over 6,000 invasive and noxious weed infestations recorded on the Forest[13]. The populations are widely dispersed with about 80 percent in small patches. The remaining populations are in patches exceeding 5 acres. In the Southwestern Region, the Forest is second in acres treated of national forests in the Southwestern Region (FACTS 2007)[14].

SOILS

Soil is an integral part of ecosystem diversity. This section of the report summarizes reference and current conditions for characteristics that represent compositional, structural and functional

[13] National Resource Inventory System (NRIS) data accessed by L. Moser on 4/17/2009.
[14] FACTS is the Forest Activity Tracking System, a national database for treatments in many resource areas.

aspects of soil by PNVT. Characteristics selected to describe soil are soil condition, soil productivity and biological crusts. More detailed information on these characteristics and their trends is located in the *Soil Report* (USDA Forest Service 2009b) and in Appendix E.

- *Soil condition.* Soil condition is the ability of the soil to resist erosion, infiltrate water and recycle nutrients. Soil condition classes are Satisfactory, Impaired, Unsatisfactory and Inherently Unstable[15]. Departures levels in soil condition were identified as low, moderate, or high[16] based on acreage differences between current and historic soil condition by PNVT. Percent soils in satisfactory condition under reference conditions is the estimated amount of satisfactory soil conditions before human activities had major influences and disturbances on soil condition (i.e., Pre-European settlement) based on correlated Terrestrial Ecosystem Survey (TES) ecological reference sites.

- ***Soil productivity.*** **Soil productivity is a combination of soil organic matter, litter cover and estimated understory and forage production. Understory and forage production values overlap and production can be variable depending on site quality. Forage values were used because they represent the structural and compositional components of the understory most influenced by current and historical livestock management and by wildlife management.** TES information was used to establish reference conditions for forage and litter production and current litter cover. TES was used to describe understory and forage production reference condition values and current values were estimated from field observations made Forest-wide (USDA Forest Service 2009f). Organic matter thickness was derived from thickness of the organic surface horizon through soil classification (USDA Forest Service 2007a). Relative departures from reference condition were rated as low and moderate[17] and are estimates comparing historic and current organic matter (litter cover, and understory and forage production) based on information in the TES and field observations.

- ***Biological soil crusts.*** **Biological crusts are crusts of soil particles formed by living organisms (algae, mosses, lichens) in arid areas. They are important ecological members because they hold soil in place, help retain moisture and improve soil nutrients by fixing atmospheric nitrogen. Crusts are slow growing and vulnerable to trampling, burial (such as with erosion), fire, and interactions with some native shrubs such as sagebrush.** Literature review and extrapolation from field sites were used to estimate the extent and disturbances to biological crusts on the Forest. Personal

[15] *Satisfactory*: Soil function is being sustained and soil is functioning properly and normally. *Impaired*: The ability of soil to function properly and normally is reduced and/or there is increased vulnerability to degradation. *Unsatisfactory*: A loss of soil function has occurred such the soil is unable to maintain resource values, sustain outputs or recover impacts. Improved management practices or restoration may be warranted. *Inherently unstable*: Soils are naturally eroding faster than they are renewing and are functioning normally. There is a need to determine cause and degree of decline in soil function. Changes in land management practices or preventive measures may be appropriate.

[16] *Low* signifies that $\leq$ 34% departure between current and historic soil condition. *Moderate* signifies a departure between 34 %-66% and *high* departure is a difference of $\geq$ 67%,

[17] For litter cover – low is a departure $\leq$33% difference between current and historic vegetative ground cover and moderate is > 33%. Departures in forage production and coarse-woody material were not quantitative values but included in overall departures as qualitative interpretations of noticeable differences between historic and current composition and diversity.

observations below the north rim of the Grand Canyon suggested reference conditions of 5-25% coverage in the Piñon Juniper Woodland PNVT, especially on coarse-textured soils. The North Rim site is similar to the Piñon Juniper Woodland and Piñon Juniper Evergreen Shrub PNVTs on the Forest.

Cottonwood Willow Riparian Forest

Reference Condition: Historically, the soil condition in this PNVT was mostly satisfactory. Soil productivity, however, were inherently low. Soils occur on both higher lying stream terraces and lower-lying floodplains in this PNVT, which naturally occurs in scattered locations on the Forest.

Current Condition: Current soil conditions are mostly impaired because the majority of acreage occurs on higher lying stream terraces where there is high departure from reference conditions. In general, where recreation disturbance occurs, the higher lying stream terraces have lower surface litter, understory production, poor species composition, and more visible sheet and rill erosion compared to reference conditions. These soils have reduced ability to recycle nutrients and resist erosion.

In contrast, surface litter production is higher on floodplains and there is a higher diversity and improved composition of species. Floodplains are subject to frequent flooding, and therefore have moister soils, greater vegetative productivity, and more protective vegetative ground cover to resist erosion than higher lying terraces. Overall soil productivity is low and departed on stream terraces, but is close to reference conditions on floodplains.

Projected future condition and trends: Under current management (improved grazing strategies and exclusion of livestock), overall soil condition and productivity are trending slowly towards reference conditions in most areas, and litter, vegetation composition, and understory productivity are expected to improve. In some areas, however, both soil condition and productivity are trending away from reference conditions where improved grazing strategies have not yet been implemented, as well as in high recreation impacted areas such as Fossil Creek and other major tributaries to the Verde River.

Comparison of current, reference and projected future conditions: There is a high departure in soil condition and moderate departure in soil productivity because most of the acreage that is departed occurs on stream terraces where most recreation use occurs. Current management is resulting in improvements and a trend towards reference conditions in most locations. There are localized areas where the trend is away from satisfactory conditions due to high recreation use or where improved cattle grazing strategies have not yet been implemented.

Desert Communities

Reference Condition: Historically, Desert Communities PNVT had mostly satisfactory soil conditions with adequate vegetative ground cover to resist erosion and ability to infiltrate water and recycle nutrients. Soil productivity overall was low, but maintained with sparse, diverse herbaceous understories and low understory and forage productivity.

Current Condition: The Desert Communities PNVT currently has mostly unsatisfactory soil conditions. Species composition at times can be poor and variable. There are few herbaceous species, including grasses, evident during dry years in areas dominated by creosote bush (a species that releases a toxin to suppress the growth of nearby plants).

Herbaceous and forage productivity is variable from year to year based on precipitation. In wet years, the interspaces between shrubs can be filled with ephemeral annual forbs and grasses, a typical desert flora. In more recent years, invasive annual grasses have been invading these interspaces. Most of these soils show evidence of compaction, reduced soil porosity and low litter cover. In creosote dominated parts of this PNVT, there are numerous gullies present. While some of the gullying is due to the highly erodible soil types in an arid system, there can be insufficient protective vegetative ground cover to prevent accelerated erosion as a result of past grazing activities and low natural vegetative ground cover in dry years.

Projected future condition and trends: Soil condition is projected to remain unsatisfactory with a static trend over the next couple of decades due to high level of soil disturbance and limited annual precipitation received especially if drought persists.

Comparison of current, reference and projected future conditions: Soil condition is moderately departed with a static trend. There is declined nutrient cycling, reduced ability to infiltrate water, and the inability of soil to resist erosion.

Soil productivity has a moderate departure and a static projected future trend. Soil productivity is very low overall with very low surface litter and very low understory and forage productivity. Current grazing strategies and restricted cross-country Off Highway Vehicle travel should very slowly move soil organics and vegetative production towards reference condition with normal precipitation. Soil conditions, however, would remain static with continued drought.

Semi-Desert Grasslands

Reference Condition: Historically, soil condition was satisfactory, with more litter cover and higher understory and forage productivity. Soil productivity was inferred to be maintained with higher than current levels of soil litter cover, organic matter, and understory and forage productivity.

Current Condition: There are relatively large amounts of impaired and unsatisfactory soils in the Semi-Desert Grasslands PNVT, resulting in reduced nutrient cycling functions (low amount of litter, low organic matter, and poor species composition) and the decreased ability of soil to infiltrate water. This is evidenced by locally compacted soils resulting in moderate departure from reference conditions. Soil productivity is moderately departed from reference conditions because it has relatively low litter and organic matter, and low understory and forage productivity.

Projected future condition and trends: Soil condition is projected to move slowly towards reference condition because with implementation of the current grazing strategies and road closures, soil nutrient cycling function should slowly improve. The projected trend, however, would be static under drought conditions. Soil productivity levels are projected to move slowly towards reference condition under current management. Soil productivity is expected to decline

in areas infested with noxious and/or invasive weeds, but this is projected to be minor in acreage extent.

Comparison of current, reference and projected future conditions: Both soil condition and soil productivity are moderately departed from reference conditions due to historic and current grazing strategies, lack of fire, scattered trees (juniper-grassland ecotones), and improperly located roads. Both factors are projected to have a static trend because the trend towards reference conditions, as improved grazing strategies are implemented and roads are closed, will be very slow due to the arid climate. This trend will be also slowed due to the continued lack of fire.

Mixed Broadleaf Deciduous Riparian

Reference Condition: Historically, there were mostly satisfactory soil conditions, and soil productivity was inherently low but within the normal range of historic variability.

Current Condition: Currently there are mostly satisfactory soil conditions. The soils generally have high amounts of protective litter and plant cover and are not compacted. Isolated areas may be in impaired or in unsatisfactory condition. Although soil productivity is currently low on higher lying stream terraces and high along floodplains, it is functioning normally to sustain ecological systems.

Projected future condition and trends: Most of this PNVT is located in areas with no motorized or livestock access and, therefore, has limited soil disturbance. This is not projected to change.

Comparison of current, reference and projected future conditions: Under current management, the departure from reference conditions is low, and the projected trend is static for both measures of soil health.

Great Basin Grassland

Reference Condition: The PNVT had mostly satisfactory soil condition under reference conditions. Soil productivity was moderate to high with adequate surface litter to maintain soil productivity, and high understory and forage production. It was variable depending on terrestrial ecological unit.

Current Condition: Current soil conditions are mostly impaired and unsatisfactory. Soil nutrient cycling and hydrology functions are appreciably reduced, primarily due to local weather such as drought and grazing by cattle and wildlife. From a soil productivity standpoint, understory and forage vigor and production is reduced due to herbivory, scattered trees (juniper-grassland ecotones) and drought. Surface litter is slightly reduced from reference conditions.

Projected future condition and trends: Under current management, the trend is slowly towards reference condition for soil condition and soil productivity.

Comparison of current, reference and projected future conditions: Soil condition is highly departed from reference condition. Soil productivity is moderately departed from reference condition. Both are projected to move slowly towards reference condition under current

management. With normal precipitation, surface litter, understory and forage vegetation production, and soil organic matter would improve. Elk grazing, however, may reduce the rate of improvement to a limited extent.

Interior Chaparral

Reference Condition: The soil condition in this PNVT under reference conditions is mostly inherently unstable, due to steep slopes. Chaparral communities are highly adapted to fire and have the resiliency to naturally regenerate vegetation and to protect soil productivity over time. Soil productivity for this PNVT is naturally generally low.

Current Condition: Current soil condition is similar to reference condition. Litter cover is similar to reference conditions and sufficient to protect the soil from accelerated erosion. Soil productivity has changed little from reference conditions and is functioning normally.

Projected future condition and trends: The projected trends for soil condition and soil productivity are static because soils in this PNVT are inherently unstable and have low productivity.

Comparison of current, reference and projected future conditions: Both the current soil condition and soil productivity are similar to reference condition. This is not projected to change in the future.

Piñon Juniper Evergreen Shrub

Reference Condition: Historically, there were mostly satisfactory soil conditions. Soil productivity overall was moderate with moderate surface litter and understory and forage production.

Current Condition: Current soil conditions are mostly impaired due to a decline in nutrient cycling and the ability to resist erosion. Current litter and plant cover is low, and species composition is poor. Visual sheet and rill erosion are common in areas of high tree density and high canopy cover. Canopy cover greater than about 40% inhibits the growth of understory vegetation that holds the soil in place.

Currently, soil productivity is low to moderate overall with reduced surface litter and understory and forage production in areas where canopy cover exceeds 40%.

Projected future condition and trends: Under current management, soil condition is projected to slowly move away from reference conditions because the rate of implementation of vegetative treatments is too slow to mitigate soil loss or maintain soil nutrient cycling functions. Although thinned areas are projected to move towards reference conditions fairly rapidly, the rate of thinning is too slow to avoid landscape level accelerated soil loss. Current cattle grazing strategies should improve the herbaceous understory somewhat, but not enough to improve overall productivity (including forage production) in high canopy cover areas.

Comparison of current, reference and projected future conditions: Both soil condition and soil productivity are moderately departed with trends towards reference conditions where canopy

cover is less than 30%, and trends away from reference conditions where canopy cover exceeds 30%.

Piñon Juniper Woodland

Reference Condition: Historically, the Piñon Juniper Woodland PNVT had mostly satisfactory soil conditions, and soil productivity was moderate overall with moderate surface litter and understory and forage production conditions.

Current Condition: Currently, about one third of the PNVT has impaired and unsatisfactory soils, mainly associated with areas that have greater than about 40% canopy cover. This results in these areas having reduced nutrient cycling and increased erosion. Current litter and plant cover is low, species composition is poor, and visual sheet and rill erosion are common in areas with high tree density. Soil productivity is overall low to moderate with reduced surface litter and low forage production. The areas with low productivity are associated with unsatisfactory and impaired soils. Soil productivity has declined over time and is probably due to fire suppression and loss of understory vegetation that would have carried fire.

Projected future condition and trends: Under current management, treatment rates are about 900 acres/year or 0.003 % of the PNVT/yr. At this rate, it would take over one hundred years to thin all unsatisfactory and impaired soils. Similar to the Piñon Juniper Evergreen Shrub PNVT, many areas are eroding faster than they are renewing themselves putting soil productivity at risk. It takes dozens of years to build one inch of soil in this PNVT. Overall, soil condition is projected to move slowly away from reference condition except in areas where the trees have been thinned. In thinned areas, soil condition should move towards reference condition with the return of an herbaceous understory.

Comparison of current, reference and projected future conditions: There is a moderate departure for both soil condition and soil productivity with trends towards reference conditions where the canopy is less than 30% and trends away from reference conditions where canopy is greater than 30%. The lack of fire has contributed to the development of areas with high canopy cover and a loss of herbaceous understory. Herbaceous understory helps hold soil in place and carries fire. Consequently, structure, composition and processes on about a third of the PNVT are departed from reference conditions.

Wetland Cienega

Reference Condition: Historically, soil condition was mostly satisfactory. In reference condition, soil productivity was high overall, with both high surface litter and understory and forage production.

Current Condition: Currently, most of the Wetland Cienega PNVT on the Forest is highly departed from reference condition. There is a high amount of unsatisfactory soils due to a combination of effects from legacy grazing that goes back to the early 1900‘s, wildlife herbivory, and managed grazing to a lesser extent. Soils are commonly compacted with reduced porosity, litter, vegetative cover, and production that impair nutrient cycling functions. Soil productivity is moderate and departed from reference condition where the wetlands are unfenced. In these areas, there have been appreciable reductions in surface litter and vegetation production.

Projected future condition and trends: Under current management and conditions, the projected trend is static for both soil condition and soil productivity due to herbivory by cattle and elk. Herbivores are attracted to isolated water sources and the associated vegetation, particularly during drought conditions. Although management of cattle and fencing of wetlands from herbivores can improve soil condition over a portion of the PNVT, herbivory will maintain unsatisfactory soil conditions over the majority of these wetlands. Under current management and conditions, the projected trend in the future is static, but still departed from reference conditions, primarily due to continued high levels of herbivory. Elk numbers are predicted to remain relatively static.

Comparison of current, reference and projected future conditions: Soil condition is highly departed, and soil productivity is moderately departed from reference conditions in unfenced wetlands. This is not expected to change because herbivory by elk is not expected to change. Wetlands excluded from any grazing trend rapidly towards satisfactory soil conditions and improved soil productivity. Unfenced wetlands, however, are expected to remain departed from reference conditions.

Ponderosa Pine

Reference Condition: Historically, soil conditions were satisfactory. Soil productivity was moderate with high surface litter and moderate understory and forage production.

Current Condition: Current soil conditions in most areas are similar to reference conditions. Most areas have high amounts of protective litter cover protecting the soil from accelerated erosion. However, nutrient cycling is nearly impaired because nearly 83% of the PNVT has a closed canopy. Closed canopy areas have reduced solar radiation and abundant litter, which can prohibit germination and establishment of herbaceous vegetation that holds soil in place and carries fire. Areas with closed canopies and high densities of trees, however, do not affect the ability of the soil to produce tree biomass. Soil productivity in Ponderosa Pine is considered to have a low to near moderate departure from reference conditions. Surface organic matter and litter is currently similar to reference condition. There is a reduction in understory and forage and possibly coarse-woody material (>3” diameter), but not enough to affect long-term soil productivity.

Projected future condition and trends: Under current management, the overall projected trend is static, but the areas of dense trees and high canopy closure are vulnerable to unnatural wildfire. High burn severity fires pose a risk to soil condition and watershed condition in areas where soils have a moderate to high erosion hazard, which account for nearly a third of the PNVT. Taking into account the potential for landscape level watershed degradation following wildfire disturbances, the trend in soil condition on about one-third of this PNVT could be considered away from reference conditions where the tree density is too high and untreated (unthinned or unburned). In open areas, or areas that are treated, nutrient cycling function would improve to satisfactory condition in treated areas and remain static or decline in untreated areas. Soil productivity is projected to remain static. It would take a couple of decades to treat impaired soils to improve understory and forage production under current management and implementation rates.

Comparison of current, reference and projected future conditions: There is currently a low departure from reference condition. Projected trends are static for both soil condition and soil productivity.

Montane Willow Riparian Forest

Reference Condition: Historically, this PNVT had mostly satisfactory soil conditions, and soil productivity was generally maintained.

Current Condition: Montane Willow Riparian has mostly satisfactory soil condition with high amounts of litter and plant cover. Little has changed from reference conditions, and therefore, Montane Willow Riparian Forest has a low departure from reference conditions. Overall, soil productivity is functioning normally, and can maintain soil productivity levels necessary to sustain ecological systems. There are isolated, unmapped areas in the Upper Clear Creek watershed not included in the 557 acres delineated in this PNVT that have unsatisfactory soil conditions due to past and current herbivory (personal communication, Steinke, 1995- 2004).

Projected future condition and trends: Under current management, both soil condition and productivity are projected to remain static in the future.

Comparison of current, reference and projected future conditions: Current soil condition and soil productivity is similar to reference condition. Projected trends are static for both soil condition and soil productivity.

Montane Subalpine Grassland

Reference Condition: This PNVT had mostly satisfactory soil conditions, and soil productivity was generally maintained.

Current Condition: Montane grasslands (areas lower than about 7,200 feet) currently have relatively large amounts of impaired soils. These soils have low vegetative ground cover, poor species composition and productivity, and show signs of extensive compaction and reduced ability to infiltrate water. Subalpine grasslands (areas higher than 7,200 feet) have more extensive vegetative ground cover, good species composition and plant productivity, and porous soils.

Projected future condition and trends: The projected future trend for soil condition in the montane portion of the PNVT is static. Areas of impaired soils and reduced soil productivity are expected to remain impaired (static) due to continued grazing, especially by elk. Trends are toward reference condition in isolated areas where grazers are excluded; however, these are in very limited areas of the PNVT. Currently, both Montane and Subalpine portions have moderate to high overall soil productivity. Montane portions, however, have low to moderate surface litter and low to moderate herbaceous production and, thus, are departed from reference conditions for these two productivity characteristics. Areas of reduced soil productivity are expected to continue in the future due to grazing, especially by elk. Subalpine meadows have litter and understory and forage production near reference conditions. High soil productivity is expected to remain into the future and, thus, has a static trend.

Comparison of current, reference and projected future conditions: Soil condition in montane grasslands is highly departed with static trend and has a low departure with static trend in subalpine grasslands. Soil productivity is moderately departed with a static trend in montane grasslands and has a low departure with a static trend in subalpine grasslands.

Dry Mixed Conifer

Reference Condition: Historically, the Dry Mixed Conifer PNVT had mostly satisfactory soil conditions, and soil productivity was functioning within the HRV.

Current Condition: Soil condition and productivity are similar to reference conditions. Overall, there are high amounts of protective litter to prevent accelerated erosion. Soil productivity is functioning normally and can maintain levels necessary to sustain ecological systems.

Projected future condition and trends: These conditions are projected to maintain in the future.

Comparison of current, reference and projected future conditions: This PNVT has mostly satisfactory soil condition and is similar to reference conditions. Soil productivity is also similar to reference conditions. It is generally moderate, functioning normally, and can maintain levels necessary to sustain ecological systems. Projected future trends for both characteristics are static.

Spruce Fir

Reference Condition: Historically, the Spruce Fir PNVT had mostly satisfactory soil conditions, and soil productivity was functioning within the HRV.

Current Condition: Soil condition and productivity are similar to reference conditions. Overall, there are high amounts of protective litter to prevent accelerated erosion. Soil productivity is functioning normally and can maintain levels necessary to sustain ecological systems.

Projected future condition and trends: These conditions are projected to maintain in the future.

Comparison of current, reference and projected future conditions: The satisfactory soil conditions are little changed between historic and current conditions. These soils have high amounts of vegetative ground cover to prevent accelerated erosion. Likewise, soil productivity is similar to reference conditions. Soil is functioning normally, and maintaining levels necessary to sustain ecological systems. There is a static trend from current condition to projected future soil condition and productivity.

Alpine Tundra

Reference Condition: The soil condition for Alpine Tundra is mostly inherently unstable. Soil productivity was normally generally low, functioning normally, and maintaining levels necessary to sustain ecological systems.

Current Condition: The soil condition for Alpine Tundra remains mostly inherently unstable. These soils have high amounts of rock cover and normal amounts of vegetative ground cover to prevent accelerated erosion. Soil productivity also has changed little from reference conditions.

Soil productivity remains normally generally low, functioning normally, and maintaining levels necessary to sustain ecological systems.

Projected future condition and trends: A static trend for both soil condition and soil productivity is predicted into the future under current management.

Comparison of current, reference and projected future conditions: This PNVT has low departure from reference condition for both soil condition and soil productivity with a static trend.

KEY FINDINGS

This section summarizes departures between reference and current conditions, and associated trends, for the two soil characteristics and for biological soil crusts.

Forestwide Soil Condition: Historically, most areas on the Forest (89%) are inferred to have been in satisfactory soil condition and about 11% of the areas were inherently unstable. Currently, about 62% of the soils are in satisfactory soil condition, about 20% are impaired, about 7% are in unsatisfactory condition, and about 11% are inherently unstable. Human disturbances during the last 100 – 125 years are believed to have caused impacts and declines in soil condition (USDA Forest Service 2009b). Major disturbances that were absent historically include: livestock and elk herbivory, vegetative treatments, dispersed recreational and off highway vehicle use, and establishment and use of roads and trails. Fire is a disturbance that existed historically, but is now largely absent at past frequencies and severities. Historic fire regimes maintained many portions of the Ponderosa Pine and Piñon Juniper Evergreen Shrub PNVTs in open stands with more herbaceous and vegetative ground cover that supported satisfactory soil conditions (USDA Forest Service 2007a).

Twenty seven percent of the soils on the Forest are departed (unsatisfactory and impaired). As shown in Figure 5, eight PNVTs have moderate or high departure between reference and current satisfactory soil conditions (Montane Subalpine Grassland, Wetland Cienega, Piñon Juniper Woodland, Piñon Juniper Evergreen Shrub, Great Basin Grassland, Semi-Desert Grassland, Cottonwood Willow Riparian Forest, and Desert Communities). These departures indicate a reduction or loss in soil function and the possibility that they may not be able to sustain ecological functions and soil productivity.

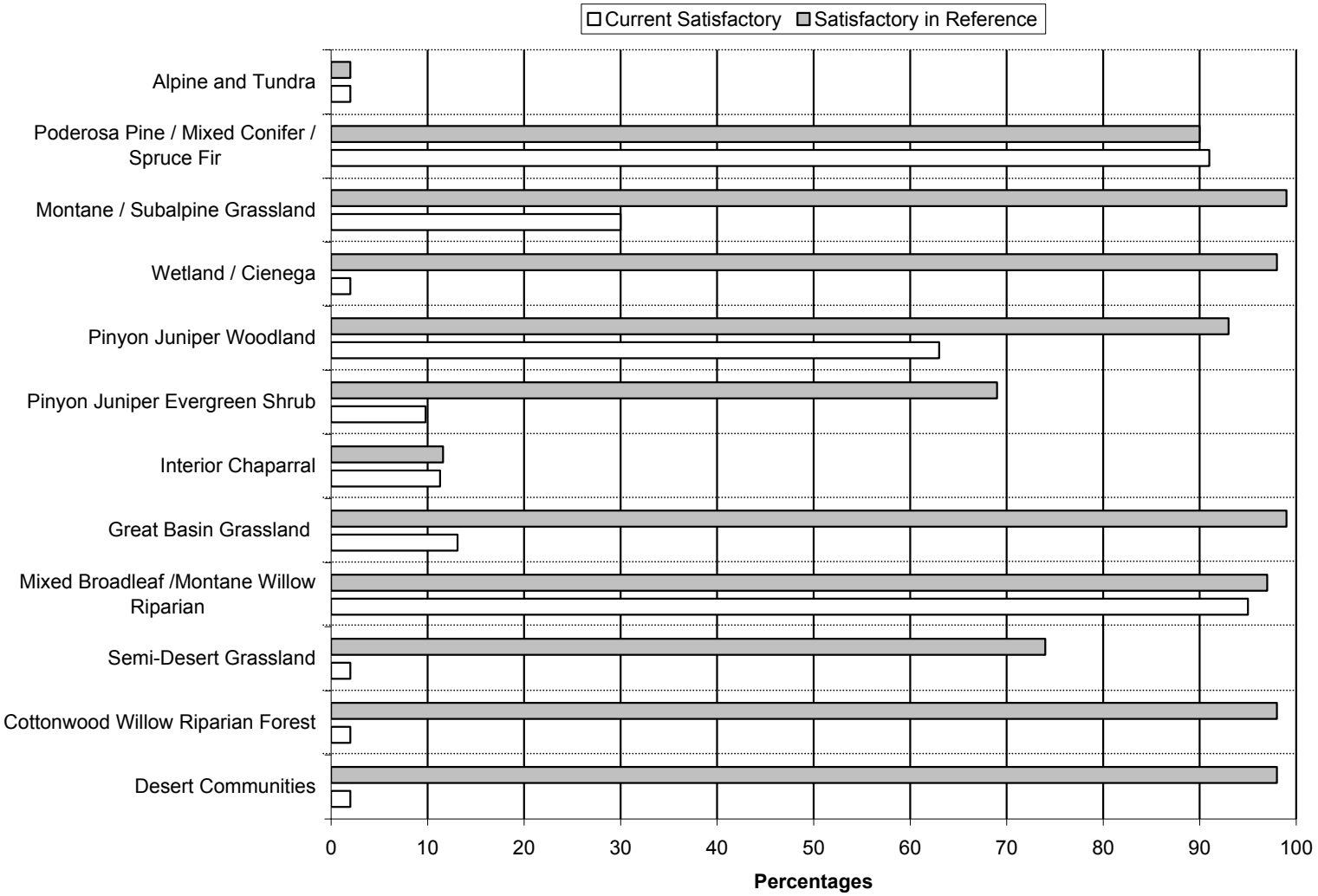

Figure 5: Comparison of Percentages of Reference to Current Satisfactory Soil Condition.

Forestwide soil productivity: Productivity can vary widely within a PNVT based on the site potential. In general, the most productive soils are within Montane Subalpine Grasslands and Wetland Cienega PNVTs followed by Great Basin Grassland. These soils have high amounts of organic matter and are capable of producing the greatest amount of understory and forage under conditions of the PNVT. Current understory and forage productivity appears to be low to moderate, and thus, could be improved.

The soils with the lowest productivity and lowest amount of organic matter are located in Riparian Forests, Desert Communities, and Alpine Tundra PNVTs. These PNVTs cannot be expected to produce high amounts of understory and forage because they have low amounts of surface organic matter due to dry climate or having been recently formed.

Piñon Juniper Woodlands, Piñon Juniper Evergreen Shrub, and Ponderosa Pine PNVTs currently have low to moderate soil productivity (organic matter, and understory and forage production) but have the potential, based on reference condition, to become more productive and produce higher amounts of understory in areas with low canopy cover. As canopy cover decreases through fire, insect and drought outbreaks, or vegetative treatments, herbaceous understory and forage production are anticipated to increase.

Forestwide biological soil crusts: Biological soil crusts are commonly found in semiarid and arid environments (Belnap 2003). Reference conditions are unknown, but are expected to have contained greater crusting extent due to fewer disturbances. Biological soil crusts have been observed in coarse textured soils predominantly in Piñon-Juniper Woodlands, Piñon-Juniper Evergreen Shrub, Semidesert Grasslands and Desert Communities PNVTs. Areas where crusts have been observed currently cover less than 5% of the soil surface; however, quantity and extent of departure is unquantified.

Current observed disturbances on the Forest include livestock and elk herbivory and motorized vehicle impacts that remove portions of the soil crust. Because the Grand Canyon North Rim site is similar to the Piñon Juniper Woodland and Piñon Juniper Evergreen Shrub on the Forest, recreation and grazing-related disturbances likely created current departures. Recovery times are generally measured in decades or centuries (Belnap 2003). The future trend is projected to be static because current disturbances are likely to continue.

AQUATIC SYSTEMS

This section of the report describes the Forest‘s contributions to ecological sustainability of aquatic systems at multiple scales - 4th code watershed, smaller 5th code watershed, and the Forest.

Contributions are described in terms of definable or measurable characteristics that represent composition, structure, and functional aspects of aquatic systems. Characteristics discussed include: surface water, groundwater, riparian condition, water quality, and aquatic species.

As mentioned previously, analyses of 4th code watersheds utilized the National Hydrologic Dataset to allow comparisons of features within and outside the Forest boundary. Fifth code watershed analysis used the more detailed Forest GIS geodatabase that contains Forest information only. Current conditions are compared to reference or historical conditions along

with projected trends or ecological trajectory under current management. Trend can be either towards reference conditions, away from reference conditions, or static (no change). An unknown condition or trend means that no data is available for the indicated aquatic characteristic. Information used in this analysis is contained in the report, *An Evaluation of Water Resource Characteristics, and their Contribution in Ecosystem Diversity and Ecological Sustainability* (USDA Forest Service 2009a).

Aquatic systems are subject to a number of disturbances. The following information provides context for understanding disturbances and departures in aquatic systems.

Flooding: Flooding affects riparian vegetation and stream courses in all PNVTs. Flooding may cause localized soil loss, sediment delivery and reduced water quality in the stream channel, streambanks, and floodplains if they are not well protected with vegetative ground cover. Flooding, however, also helps regenerate cottonwoods and willows because the resulting deposition of silt creates appropriate soil and moisture conditions for establishment, germination and growth of these species. Frequent and flash flooding is a natural disturbance process. Flash flooding can occur in perennial, intermittent and ephemeral streams in all PNVTs where short duration, high intensity storms occur. Wide variation in flow of individual streams has been reported. For example, Oak Creek near Page Springs (near the south end of the Forest) reached a maximum flow of 26,400 ft^3 in February 1980 and a minimum flow of 6 ft^3 in July 1940 (USGS 2003).

Drought: Periodic droughts have been reported since European settlement. Tree ring studies have shown that droughts have occurred throughout the last millennium (Swetnam and Betancourt 1998). Severe drought in the 1890‘s resulted in large scale mortality of livestock. The most extreme drought in the last 400 years occurred from about 1942-57 and resulted in broadscale plant dieoffs in shrublands, woodlands, and forests and accelerated shrub invasion of grasslands. Recently, the Forest experienced several years of drought (since about 1996), punctuated by periods of seasonal moisture at or above the long-term mean. Reduced precipitation results in reduced upland vegetative growth, reduced surface organic matter and ineffective vegetative ground cover, which put the soil at risk of accelerated erosion, runoff, and sediment delivery to connected streams during storm events. As vegetation dries out, there is an increased potential for wildfire spread and subsequent accelerated erosion, watershed degradation, and increased sedimentation into connected waters.

Dams and impoundments: Dams and impoundments block the normal flow of streams and capture some of the stream flow, usually from periods of high flow or flood events. Large impoundments on the Coconino NF include CC Cragen reservoir on East Clear Creek, and Upper Lake Mary and Lower Lake Mary on the now intermittent Walnut Creek, and Knoll Lake in Leonard Canyon. CC Cragen is operated by the Salt River Project and up to 15,000 acre-feet/year are diverted into the East Verde and Verde Rivers for use in the Salt River Project Water Users Association in Phoenix. Upper Lake Mary and Lower Lake Mary are operated by the City of Flagstaff for Flagstaff domestic city water. Knoll Lake is operated by the Forest for recreation, livestock, and wildlife use. The majority of dams and impoundments are earthen stock tanks that are sometimes constructed in shallow wetlands and built to provide water for permitted livestock. These are also used by wildlife species. Dams trap sediments that would otherwise move downstream or disperse through the channel system. The trapping of sediments may affect the ability of downstream channels to replenish alluvial banks and terraces.

Stocktanks in ephemeral to semi-permanent wetlands alter the permanency and depth of water, surface area of the wetland, and the natural shoreline.

Water withdrawals: Withdrawals from both surface water streams and connected groundwater aquifers may affect streamflow. Diversions for private irrigation use are common and have been in place along Oak Creek, Beaver Creek, West Clear Creek, and the Verde River since the early 1900s. A few Forest diversions exist on Oak Creek and Wet Beaver Creek near campgrounds and administrative sites.

Stream flow can decrease during irrigation season. Irrigation ditches are permitted by Arizona Department of Water Resources where a certified water right or claim exists. In the Upper Verde River and Canyon Diablo 4th code watersheds, streamflow and some well data indicate a recent downward trend in streamflow and groundwater levels adjacent to Flagstaff and Verde Valley cities. This is most prominent in areas that have the most well pumping on private lands (USDA Forest Service 2009a).

Roads: Roads located adjacent to and connected to stream courses serve to concentrate and accelerate water flow and thus may increase peak flows over natural levels causing decreased channel stability, riparian function, and water quality. Culverts can interrupt stream flow and become barriers for the movement of aquatic species.

Herbivory: Cattle and sheep grazing have occurred on the Coconino since the late 1800‘s. Sheep grazing makes up a small portion of current permitted use. Because of lush riparian vegetation and limited distribution of water, cattle and wildlife concentrate around accessible water sources such as perennial streams, stocktanks, springs, seeps, wetlands, and lakes. Concentrated use has been observed to reduce vegetative ground cover and riparian vegetation, and contribute to accelerated erosion, soil compaction and sedimentation to connected perennial waters and reduce or impair water quality.

Other human uses: Concentrated and sustained swimming can change water quality by increasing *E.coli* bacteria beyond acceptable levels. The septic and sewage systems of homes and buildings built close to water can leak a variety of pollutants into nearby waterbodies.

Extent

The Coconino covers about 20% of the total extent of the 4th code watersheds that overlap the Forest, and contributes a proportionally higher 30% of perennial stream miles. As mentioned previously, the Coconino‘s greatest contribution is to the sustainability of the Middle Little Colorado River 4th code watershed because the Forest contains 55% of the perennial stream miles, but only 15% of this 4th code is on the Forest. The Coconino encompasses about 44 percent of the total extent of the 5th code watersheds and 38% of perennial stream miles. Maintaining favorable conditions of water flow (quantity, quality, and timing) in perennial streams is critical in sustaining ecosystem diversity both on the Forest and throughout the extent of perennial stream miles off-forest.

Table 26 shows the amount of stream miles on the Forest by 4th and 5th code watersheds. A map of these 5th code watersheds in relationship to the Forest is shown in Figure 6. Forest management and conditions within 5th code watersheds with large proportional extents, such as

Upper Clear Creek, Jacks Canyon, Rio de Flag, Walnut Creek, San Francisco, Canyon Diablo, Deadman Wash, Upper Cedar Wash, Beaver Creek, Oak Creek, Fossil Creek-Lower Verde River and West Clear Creek, play a large role in overall ecological sustainability within its boundary. Conversely, Haigler-Tonto Creek, Lower Cedar Wash, Lower Clear Creek, Grindstone Wash-Upper Verde River, East Verde, Spring Valley Wash 5th code watersheds occupy less than six percent of the Forests' watersheds in total. Forest management activities that maintain perennial waters contribute less to overall ecological sustainability to these watersheds. All other watersheds occupy intermediate areas on the forest. Management activities that maintain perennial water quantity, quality, and timing of flows play an important role in overall ecological sustainability in these remaining watersheds.

Table 26: Percent of perennial stream miles by watershed on the Coconino

Fourth code watersheds	Fifth code watersheds	Percent of watershed administered by Coconino	Percent watershed perennial stream miles on Coconino
Havasu Creek	Spring Valley Wash	2.4%	0%
Middle Little Colorado River		14.7%	55%
	Upper Clear Creek	55.4%	78%
	Lower Clear Creek	4.8%	35%
	Jacks Canyon	59.2%	0%
Canyon Diablo		57%	17%
	Rio de Flag	37.7%	0%
	Walnut Creek	92.6%	0%
	San Francisco	58.1%	0%
	Canyon Diablo	37.7%	100%
Lower Little Colorado River		15.0%	0%
	Kana a Wash	29.0%	0%
	Deadman wash	89.9%	0%
	Citadel Wash	19.4%	0%
	Upper Cedar Wash	37.0%	0%
	Lower Cedar Wash	2.1%	0%
Tonto Creek		0.2%	0%
	Haigler-Tonto Creek	.8%	0%
Upper Verde River		39.5%	36%
	Cherry Creek-Upper Verde R.	15.1%	3%
	Grindstone Wash-Upper Verde R.	5.2%	10%
	Sycamore Creek	27.2%	13%
	Beaver Creek	94.8%	55%[18]
	Oak Creek	86%	44%
Lower Verde River		24.0%	21%
	Fossil Creek-Lower Verde R.	54.8%	32%
	West Clear Creek	98.5%	93%
	East Verde	4.2%	0.3%

[18] The majority of remaining stream miles is within the Forest boundary on lands in other ownership.

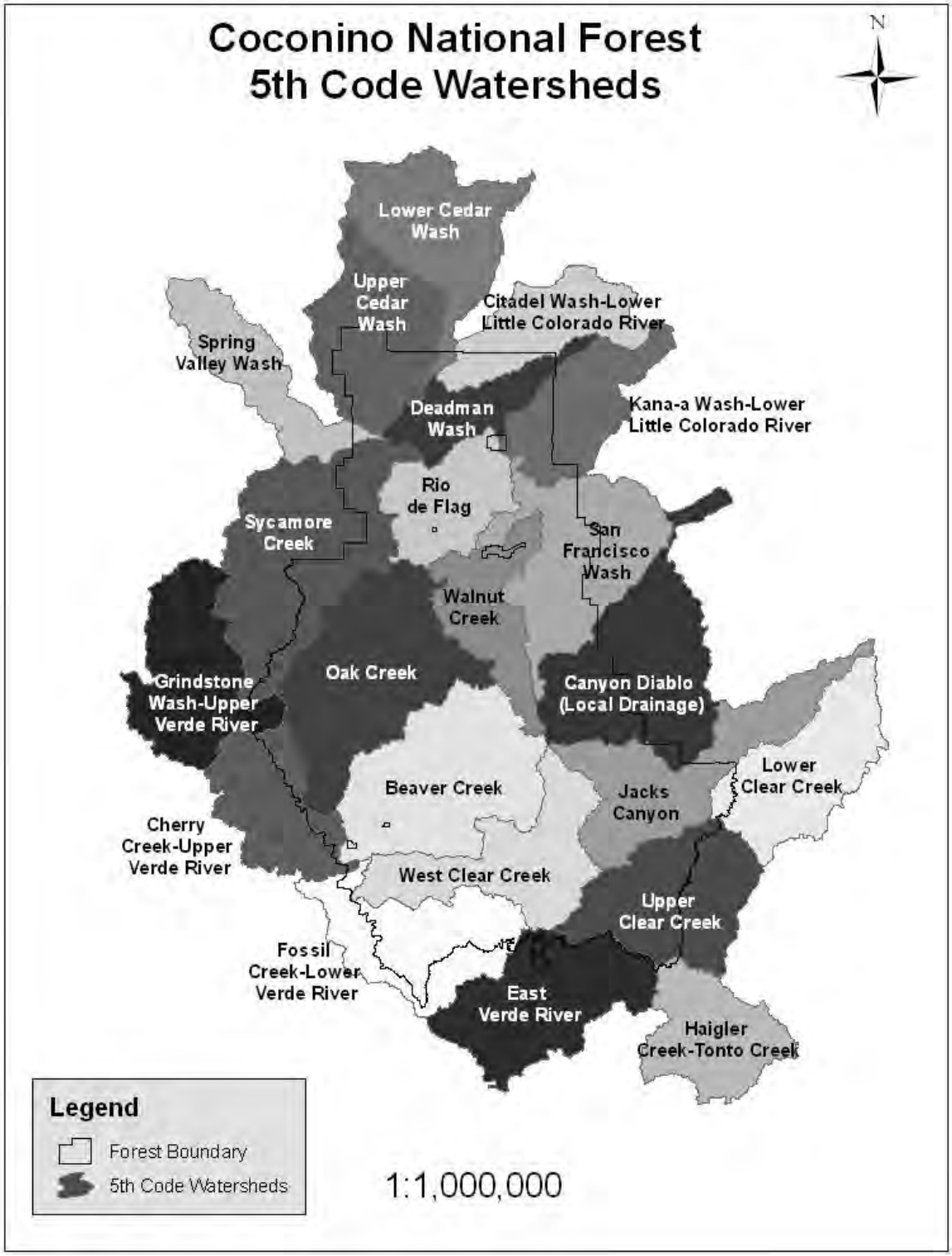

Figure 6: Map of 5th code watersheds on the Coconino National Forest

Surface water

The following section describes water bodies that have surface water year round. These water bodies include perennial streams, lakes (which includes wetland cienegas that are also discussed under PNVTs), and springs, seeps and stocktanks (which does not include wetlands).

Perennial streams

There are 224 perennial stream miles on the Forest, based on Forest data[19]. Many plant and animal species rely on perennial stream water for survival. The extent of perennial stream courses has shifted slightly over time. The Homestead Act of 1862 facilitated the transfer of some lands containing streams into private ownership, and creation of dams on East Clear Creek and Leonard Canyon formed CC Cragin Reservoir and Knoll Lake respectively. Diversions and irrigation ditches reduce stream flow along some stream segments and have been operational for many years. Most diversions and ditches are off Forest.

Visual observations[20] show that the riparian vegetation along most streams has diverse age classes. This suggests that the perennial stream extent has been present for several decades and that disturbance, such as flooding, has influenced vegetation composition and structure. Some streams have abandoned higher floodplains and old riparian forest vegetation, but the stream segment persists in lower lying floodplains. Some stream reaches have downcut through these abandoned floodplains to form a straighter stream segment, slightly reducing overall stream miles. It is not known how many miles have been downcut or affected.

Reference Condition: Reference levels of water yield are unknown, however research suggests that water yield in pre-settlement, open canopied ponderosa pine forests was higher than in the closed canopy forests that are prevalent today (Brown et al. 1974). Studies in paired watersheds (watersheds that are similar in nature with regards to their vegetation and soils) in Arizona have shown that there was a short-term increase in water yield following thinning in ponderosa pine forests.

Current Condition: Current surface water use on the Forest is slightly higher than in the early 1980‘s because new campgrounds and day-use areas were created in response to increased recreation use. Forestwide, livestock and wildlife are expected to continue to rely on stocktanks and perennial streams for water.

Surface flow is dependent on precipitation, and the recent drought has reduced flows in some stream reaches occupied by native fish. Surface water is currently available for administrative use, such as fire fighting and road maintenance, under the reserved water rights doctrine. Procurement and maintenance of these waters and associated water rights, however, are critical for the management and protection of forest resources. Four out of nine instream flow water rights have been procured on the Forest.

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[19] Forest data shows 43 more stream miles than the National Hydrologic Dataset (NHD) information used in the Introduction. NHD data includes areas outside the Forest and facilitates analysis at different scales. Forest data is considered more accurate and was used for analyses only at Forest scale.

[20] Visual observations of riparian vegetation along most of the Coconino‘s perennial streams have been conducted as part of riparian inventory documentation (USDA Forest Service 2009a).

Projected Future Condition and Trends: Analysis of streamflow data indicates that perennial streamflow in the Verde River watersheds has a static to slightly downward trend with the exception of Oak Creek, which is trending slightly upward (USDA Forest Service 2009a). No recent, long-term gauging, however, has occurred for streams located in the Little Colorado River watersheds. Maintaining riparian vegetation in proper functioning condition[21] is necessary in sustaining perennial stream extent and associated plant and animal diversity.

Lakes

Reference Condition: Historically, there were more natural lakes with shoreline and standing water than current conditions. They were located in natural depressions and were largely precipitation dependent. Construction of dams and other improvements began in the early to middle part of the 1900's. They were constructed primarily for municipal water use, recreation, and livestock, resulting in the conversion of 13 lakes to reservoirs.

Current Condition: The Forest's lakes and ponds are primarily distributed in the Middle Little Colorado River and Canyon Diablo 4th code watersheds, and secondarily in the Upper Verde River. There are 19,578 surface acres in these watersheds and an estimated 42% or 8,311 surface acres of perennial lakes and ponds on the Forest (USGS 2008). Of these 8,311 acres, 32% (2,645 acres) are reservoirs. Water rights are primarily owned by private entities and State, Federal, and local governments. Current uses are for domestic water consumption, recreation, fish habitat and livestock water consumption. Water rights specify location and type of use of the reservoirs and lakes.

Projected Future Conditions and Trends: Existing lakes and reservoirs are anticipated to remain unchanged in the future. No new lakes or ponds are being constructed or planned on Coconino lands.

Springs, Seeps, and Stocktanks

The National Hydrologic Dataset was used to describe the number of seeps, springs, and stocktanks. The proportional extent of seeps, springs and stocktanks are displayed in Table 27 and does not include wetlands. This information shows that the Forest has higher than expected percentages of seeps, springs, and stocktanks in the Middle Little Colorado River, Canyon Diablo, and Lower Little Colorado River 4th codes, and a higher than expected percentage of stocktanks in the Havasu Creek 4th code.

[21] Riparian areas are functioning properly when adequate vegetation, landform, or large woody debris is present to: dissipate stream energy associated with high flows, thereby reducing erosion and improving water quality; filter sediment; capture bedload and aid in floodplain development; improve flood-water retention and ground-water recharge; develop diverse ponding and channel characteristics to provide habitat.

Table 27: Proportional extent of seeps and springs, and stocktanks by 4th code watershed

4th Code Watershed	% watershed on the Forest	% springs and seeps within watershed on Forest	# stocktanks[22] within watershed on Forest	% stocktanks within watershed on Forest
Havasu Creek	0.16%	0%	9	10%
Middle Little Colorado River	15%	63%	683	26%
Canyon Diablo	57%	79%	1086	65%
Lower Little Colorado River	15%	38%	166	34%
Tonto Creek	0.2%	0%	8	0.2%
Upper Verde River	40%	27%	1776	12%
Lower Verde River	24%	12%	716	15%

Reference Condition - springs and seeps: Springs and seeps are inferred to have been distributed across numerous watersheds on the Forest because they currently exist in the five 4th code watersheds with the highest Forest extent. Although reference conditions are largely unknown, the fact that seeps and springs are well represented, or redundant, throughout all major watersheds assures the opportunity for a high level of sustainability as long as their condition is functional. They are natural water features that existed prior to Euro-American settlement and were probably functional due to lack of human disturbances. Native Americans and wildlife likely caused early disturbances. Disturbances became more extensive as homesites were developed and as livestock operations increased.

Current Condition - springs and seeps: Springs and seeps are located across five out of seven fourth code watersheds: Middle Little Colorado River, Canyon Diablo, Lower Little Colorado River, Upper Verde River, and Lower Verde River. A substantial number of the springs are developed, which probably occurred after the Homestead Act of 1862. Extent and flow of springs and seeps fluctuate in response to a lack of recharge in the associated aquifers due to drought, lack of fire, and closed forest canopies which increase evapotranspiration. Springs and seeps located adjacent to existing wells may experience reduced flow from pumping of wells on private land like that in the Upper Verde River 4th code watershed near Verde Valley municipalities. The combined effects of spring development, adjacent well pumping and surrounding landscape condition on flows are unknown.

Proper functioning condition (PFC) assessments associated with springs and seeps are limited. Where information has been collected, unfenced areas are classified as either _functional at risk‘ (FAR or at risk) or _non functional‘ due to disturbance mainly from livestock and wildlife herbivory and recreation. PFC classes are described below as they relate to riparian and wetland areas.

- Proper functioning condition (PFC): Riparian and wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to: dissipate stream energy associated with high flows, thereby reducing erosion and improving water quality; filter sediment; capture bedload and aid in floodplain development; improve flood-water

[22] Southwestern Region aquatic data assembled by K. Halverson 12/20/2006.

retention and ground-water recharge; develop root masses that stabilize banks; develop diverse ponding and channel characteristics to provide habitat for fish, waterfowl and other uses; and support greater biodiversity.

- *Functional-at-risk (FAR)*: Riparian and wetland areas that are in functional condition, but an existing soil, water, or vegetation attribute makes them susceptible to degradation. These are also referred to as _at risk‘.

- *Non-functional:* Riparian and wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, and are not reducing erosion, improving water quality, etc.

Projected Future Conditions and Trends – springs and seeps: Under current management, seeps and springs that are functioning properly are expected to remain static. Some springs and seeps, however, are projected to remain at risk or non functional due to drought, recreation, herbivory, adjacent domestic well use and closed canopies resulting from the lack of fire.

Reference Condition - stocktanks: There were no stocktanks historically. Stocktank construction for livestock watering began in the late 1800‘s. The vast majority were constructed in the mid to late 1900‘s, especially after the Second World War (post-1945) due to the availability of war surplus bulldozers.

Current Condition - stocktanks: According to the Arizona Department of Water Resources Statement of Claim filings for water rights, there are 4,444 stocktanks on the Forest in all 4th code watersheds. There are 28,606 total, on- and off-Forest in the 4th code watersheds. The Forest has a water rights database with the most up-to-date filings which lists 1,845 forest-owned claims of all types (springs, stocktanks, lakes, streams). These claims include watershed-level reserved water right claims allowing use of stock water for fire fighting and watering for road maintenance.

Stocktanks provide water for livestock and wildlife. These animals tend to congregate close to stocktanks and move soil and vegetative condition towards unsatisfactory conditions; however the spatial extent of the disturbance diminishes as distance from water increases. There are several claimed[23] stocktanks that currently are not functioning because they are breached or silted. Several stocktanks on the Forest are managed to provide habitat for leopard frog species. Some stock tanks contain nonnative aquatic species. During high water events, these species can be washed downstream into nearby fish bearing waters and potentially pose a threat to native species.

Projected Future Conditions and Trends – stocktanks: Stock tank function should remain static through time. Stocktank extent could decline slightly based on site-specific analysis on water needs in a particular area. Water rights specify the location and type of use of stock tanks.

[23] Claimed means that the Forest is pursuing obtaining a legal water right under Arizona Statute.

Groundwater

Three major groundwater basins originate on the Forest: the Little Colorado River Plateau, the Verde River, and Coconino Plateau basins. The Forest lies mainly in the Verde River and Little Colorado River Plateau basins. Areas of highest precipitation and groundwater recharge for these basins occur on Coconino National Forest lands.

Major uses of groundwater in the Little Colorado River Plateau basin are: agriculture, municipal use, power generation, and paper manufacturing. Groundwater and surface water are used for the City of Flagstaff's domestic water supply.

Major groundwater uses in the Verde River and Coconino Plateau basins are: agriculture and municipal use. Verde Valley cities rely mostly on groundwater through permitted wells in the Verde River basin.

Major uses of groundwater within the Forest in all basins include domestic water supply for Forest campgrounds, day-use areas and administrative sites and to a lesser extent, livestock and wildlife consumption.

Reference Condition: Even though reference conditions are largely unknown, it is assumed that the natural discharge/recharge in all three basins were in a steady state since there was less domestic use than today. Groundwater pumping was minimal prior to the 20th century.

Current Condition: Forest contribution to groundwater recharge is substantial in all three basins, but especially in the Verde River Basin even though recharge rates are variable and dependent on precipitation.

In the Little Colorado River Plateau and Verde River basins, the rate of groundwater pumping is greater than the rate of recharge, especially near Flagstaff and Camp Verde.

In the Verde River and Little Colorado River Basins, located within the Upper Verde and Canyon Diablo 4th code watersheds, domestic groundwater use and demand has increased since 1971. In these watersheds, streamflow and some well data indicate a recent downward trend in groundwater levels adjacent to Flagstaff and Verde Valley cities. This is most prominent in areas that have the most well pumping on private lands (USDA Forest Service 2009a).

Projected Future Conditions and Trends: Demand is predicted to exceed supply in the Little Colorado River Plateau and Verde River Basins. In preparation, the City of Flagstaff purchased water rights at the Red Gap Ranch east of the city as a potential source of groundwater because demand is predicted to exceed supply by 2020 or later.

Continued or increased pumping may negatively affect the base flow of streams that are directly connected to major aquifers and associated streams, especially the Verde River, Beaver Creek, West Clear Creek and Oak Creek, because domestic use is high adjacent to these streams. Groundwater pumping within the Little Colorado River Plateau basin may negatively affect adjacent Forest wells used for stock watering and domestic use. Groundwater pumping adjacent to springs and seeps may reduce flow, but little quantitative information is available to accurately project the extent. The downward trend in groundwater levels is projected to continue with

increasing use adjacent to the Verde Valley cities and Flagstaff; however, trends in the remainder of the area are unknown. There is an opportunity to assure sustainability of groundwater since it is located in several aquifers that are well distributed and represented throughout the Forest.

Riparian

Riparian areas are terrestrial ecosystems characterized by hydric soils[24] and plant species that are dependent on the water table or its capillary fringe zone (USDA Forest Service 2004). They include areas near springs, streams, ponds, lakes and their associated wet areas and floodplains. They collect and transport water, soil, and organic material from upslope and upstream and are basic to the hydrologic function of watersheds.

Wetland and riparian condition and extent come from Forest-specific data collected from 1990 to 2006. Proper Functioning Condition (PFC) was used to determine condition of riparian areas (USDA Forest Service 2009a). The PFC inventory for the Forest was derived from either on-site evaluation of about 75 percent of the known Forest riparian areas from 1995-2007, or from ocular estimates from site visits made by Forest personnel trained in the PFC protocol. The protocol is a consistent qualitative approach to determine how well physical processes are functioning, based on quantitative science. **Riparian and wetland condition is considered highly departed from reference conditions when 33% or more of inventoried riparian areas are functional-at-risk or non-functional. Low departure is when less than 33% of inventoried riparian areas are functional-at-risk or non-functional**.

Stream riparian

This portion of the report compares the extent and condition of stream riparian on the Coconino. Extent is described in *acres* using a riparian GIS layer from Arizona Game and Fish Department that contains on and off Forest information[25]. PNVT delineations do not fully capture riparian area extent due to the coarse map scale. Condition is described in terms of stream *miles* using Forest specific data. Forest-wide riparian conditions are variable. About 44% are in proper functioning condition, 23% are functional-at-risk, 6% are non-functional, and conditions for about 26% are unknown because they are unassessed. This does not equal 100% due to rounding error.

Reference Condition: **Reference conditions were resilient riparian areas in a proper functioning condition that sustained habitat and species that relied on riparian areas for their survival.**

Current Condition: Riparian areas are currently fairly well represented and present in three out of seven watersheds: Middle Little Colorado River (48% of the riparian acres in the watershed are on the Forest), Upper Verde River (36%) and Lower Verde River (21%), **and their redundancy in multiple watersheds offers the opportunity for sustainability as long as their condition is trending toward properly functioning. A**s displayed in Table 28, there is

[24] Soils that form under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil layer.
[25] Riparian acres are from Arizona Game and Fish Department Riparian layer derived from Landsat and Multiple Resolution Aerial Videography (USDA Forest Service 2009a).

proportionally more riparian acres on the Forest (778 linear miles of riparian areas, 165 miles of which are private) in the Middle Little Colorado River 4th code relative to the Forest extent in the watershed.

Table 28: Proportional extent of riparian acres by 4th code watershed

4th Code Watershed	Percent watershed on the Forest	Riparian acres in watershed	Percent watershed riparian acres on Forest
Havasu Creek	0.16%	0	0
Middle Little Colorado River	15%	1404	48%
Canyon Diablo	57%	0	0
Lower Little Colorado River	15%	0	0
Tonto Creek	0.2%	4585	0
Upper Verde River	40%	5425	36%
Lower Verde River	24%	8237	21%
Forest Totals at 4th Code Scale	**19.7%**	**19,651**	**22%**

Table 29 below shows that Forestwide riparian conditions are variable. Most of the perennial stream miles in the Middle Little Colorado River 4th code watershed are in PFC. The Upper Clear Creek 5th code watershed is highly departed from reference condition due to the percentage of inventoried riparian areas that are Functional-At-Risk or Non-functional, primarily in response to excessive wildlife herbivory. Less than half of the inventoried riparian areas in the Canyon Diablo 4th code watershed are in PFC. Walnut Creek has low departure with 29% of inventoried stream miles classified as Functional-At-Risk or Non-functional. Slightly over half (113 miles) of inventoried riparian in the Upper Verde 4th code watershed is Functional-At-Risk or Non-functional. Highly departed 5th codes are Grindstone Wash-Upper Verde River, Beaver Creek, and Cherry Creek-Upper Verde River.

Riparian areas outside of the Verde River located in the Cottonwood-Willow PNVT are dominated by Functional-At-Risk conditions. Overall, most riparian areas located in the Mixed Broadleaf Deciduous and Montane Willow Riparian Forest PNVTs are in PFC, but there are appreciable areas within both PNVTs assessed as Functional-At-Risk. These Functional-At-Risk areas include Montane Willow Riparian Forest PNVT at Buck Springs and Merritt Draw on the Mogollon Rim, the Fern Mountain Botanical Area (Goodwin, 2005, 2006, 2007 and Waring 1991), and portions of Wet Beaver and Oak Creeks within the Mixed Broadleaf Deciduous Riparian PNVT.

Projected Future Conditions and Trends: In general, areas currently in PFC are expected to remain in that condition based on Best Management Practice (BMP)[26] implementation for road, timber and grazing management. Some areas are inaccessible to

[26]BMPs are methods determined to be the most effective practical means of prevention or reducing pollution from non-point sources. Non-point sources are pollution sources without a single point of origin or not introduced into a receiving stream from a specific outlet. Pollutants are generally carried off the land by storm water and common sources are agriculture, forestry, channels and urban (U.S. EPA 2006).

grazing or recreation, or grazing has been removed over the past 10 years. Riparian areas with a Functional-At-Risk rating will show an upward trend where BMPs and other mitigation are effectively protecting riparian values. Areas where permitted livestock on the Coconino have been removed, such as the Verde River, have improved and will continue to do so. Progress towards reference conditions will be slowed in areas of relatively high elk grazing or in areas of high dispersed recreation.

Table 29: PFC classes by riparian stream length in fourth and fifth code watersheds on Coconino NF

Fourth code watershed	Fifth code watershed	Proper Functioning Condition (miles & percent)										
		PFC	%	FAR	%	NF	%	Non-Riparian	%	Unk[27]	%	Total miles
Havasu Creek	Spring Valley Wash	0	0	0	0	0	0	0	0	0	0	0
Middle Little Colorado R.		144	68	48	23	21	10	0.2	0	0	0	213
	Upper Clear Creek	130.2	65	48	24	21	11	0.2	0	0.6	<1	200
	Lower Clear Creek	14.1	100	0	0	0	0	0	0	0	0	14
	Jacks Canyon	0	0	0	0	0	0	0	0	0	0	0
Canyon Diablo		6	16	7	18	3	8	2	5	20	50	38
	Rio de Flag	1.8	44	0	0	0	0	0	0	2.3	56	4.1
	Walnut Creek	4.2	12	7.1	21	2.6	8	2.4	7	17.6	52	33.9
	San Francisco Wash	0	0	0	0	0	0	0	0	0	0	0
	Canyon Diablo	0	0	0	0	0	0	0	0	1.9	100	1.9
Lower Little Colorado R.		0	0	0	0	0	0	0	0	0	0	0
	Kana-a Wash-Lower Little Colorado R.	0	0	0	0	0	0	0	0	0	0	0
	Deadman Wash	0	0	0	0	0	0	0	0	0	0	0
	Citadel Wash-Lower Little Colorado R.	0	0	0	0	0	0	0	0	0	0	0
	Upper Cedar Wash	0	0	0	0	0	0	0	0	0	0	0
	Lower Cedar Wash	0	0	0	0	0	0	0	0	0	0	0
Tonto Creek		0	0	0	0	0	0	0	0	0	0	0
	Haigler Creek-Tonto Creek	0	0	0	0	0	0	0	0	0	0	0
Upper Verde R.		104	28	90	24	22	6	0	0	158	42	374
	Sycamore Creek	4.1	9	0	0	0	0	0	0	40.5	91	44.6
	Grindstone Wash-Upper Verde River	0	0	6.5	100	0	0	0	0	0	0	6.5
	Oak Creek	71.6	48	19.1	13	0	0	0	0	58.4	39	149.1
	Beaver Creek	28.2	20	31.5	23	21.4	15	0	0	59.1	42	140.3
	Cherry Creek-Upper Verde River	0	0	33	100	0.1	0	0	0	0	0	33.1
Lower Verde R.		89	18	34	76	2	0.4	5	1	25	5	152
	West Clear Creek	45.7	73	10.5	17	1.9	3	4.5	7	0	0	62.5

[27] Unknown areas were not inventoried for PFC because access is difficult. It is probable that many areas are PFC because access by people and livestock is limited and, therefore, riparian areas are not greatly disturbed.

Fourth code watershed	Fifth code watershed	Proper Functioning Condition (miles & percent)										
		PFC	%	FAR	%	NF	%	Non-Riparian	%	Unk[27]	%	Total miles
	East Verde River	0	0	0	0	0	0	0	0	0	0	0
	Fossil Creek-Lower Verde R.	42.5	49	23.1	26	0	0	0	22	25	0	87.4
Total miles & Average Percent		**342**	**44**	**179**	**23**	**47**	**6**	**7**	**1**	**202**	**26**	**778**

Wetland riparian condition

The Forest contains about 78 lentic (non-flowing, depression areas) riparian wetlands totaling about 10,186 acres[28]. Wetland types range from temporary (brief ponding of water) to permanent (sustained storage of water), depending on seasonal precipitation. Annual precipitation has a large effect on vegetative growth and water permanency.

Six out of seven affected 4th code watersheds have wetlands on the Forest: Middle Little Colorado River, Canyon Diablo, Lower Little Colorado River, Tonto Creek, Upper Verde River, and Lower Verde River. Many are located on Anderson Mesa in landscape depressions and clay soils capable of perching the water high above the true ground water table.

Reference Condition: Reference conditions consisted of precipitation-dependent resilient wetland areas in properly functioning condition that sustained riparian habitat. More than half of the 5th code watersheds have wetlands present. Wetlands are fairly well represented in these watersheds and, therefore, offer higher probability of sustainability as long as they are trending towards properly functioning condition.

Current Condition: As displayed in Table 30, 81% of the inventoried wetland acres (representing 55% of the wetlands) on the Forest are in PFC, and 9% of the inventoried wetland acres (representing 38% of the wetlands) are Functional-At-Risk. PFC assessments could not be done on the remaining acres because they are reservoirs. No wetlands are Non-functional.

San Francisco 5th code watershed has more inventoried Functional-At-Risk wetlands and associated acres than any other 5th code watershed, followed by Upper Clear Creek and Sycamore Creek 5th code watersheds.

Table 30: Acres, percentage, and number of wetlands (in parentheses) by PFC class and watershed

Fourth code watershed	Fifth code watershed[29]	Forest percent in watershed	Acres in PFC	%	Acres in FAR	%	Acres Unknown[30]	%	Total acres (#)
Middle Little Colorado River		15	1559 (9)	76	120 (5)	6	363 (2)	18	2042 (16)
	Upper Clear Creek	55	1 (1)	0.2	114 (3)	24	363 (2)	76	478 (6)
	Jacks Canyon	59	1558 (8)	99	6 (2)	1	0	0	1564 (10)
Canyon Diablo		57	6534 (15)	84	625 (17)	8	662 (1)	9	7821 (43)

[28] based on Forest data
[29] Only 5th code watersheds that have wetlands are shown.
[30] Unknown areas were not inventoried for PFC because access is difficult. It is probable that many areas are PFC because access by people and livestock is limited and therefore riparian areas are not greatly disturbed.

Fourth code watershed	Fifth code watershed[29]	Forest percent in watershed	Acres in PFC	%	Acres in FAR	%	Acres Unknown[30]	%	Total acres (#)
	Rio de Flag	38	0	0	15 (1)	100	0	0	15 (1)
	Walnut Creek	93	5620 (7)	89	24 (3)	0.3	662 (1)	10	6307 (11)
	San Francisco Wash	58	413 (8)	46	490 (10)	54	0	0	902 (18)
	Canyon Diablo	38	501 (10)	84	96 (3)	16	0	0	597 (13)
Lower Little Colorado River		15	23 (1)	61	14 (2)	37	1 (1)	3	38 (4)
	Upper Cedar Wash	37	23 (1)	82	4 (1)	14	1 (1)	4	28 (3)
	Deadman Wash	90	0	0	10 (1)	100	0	0	10 (1)
Upper Verde River		40	153 (2)	60	101 (3)	40	0	0	254 (5)
	Beaver Creek	95	151 (1)	99	1 (2)	1	0	0	152 (3)
	Sycamore Creek	27	2 (1)	2	100 (1)	98	0	0	102 (2)
Lower Verde River		24	25		1		0	0	(5)
	West Clear Creek	99	3 (3)	75	1 (2)	25	0	0	4 (5)
	East Verde River	4	1 (1)	100	0	0	0	0	1 (1)
	Fossil Creek-Lower Verde River	55	21 (1)[31]	88	3 (2)	12	0	0	24 (3)
Tonto Creek	Haigler-Tonto Creek	0.8	1(1)	100	0	0	0	0	1 (1)
Totals		44	8295 (43)	81	865 (30)	9	1018 (5)	10	10,178 (78)

[31] Stehr Lake is trending to montane meadow due to lack of water.

Projected Future Conditions and Trends: In general, areas currently in PFC are expected to remain static because of implementation of Best Management Practices (BMP) designed to protect resources. Wetlands classified as Functional-At-Risk are not expected to improve where they are unfenced. Elk and cattle utilization is higher in unfenced areas near water, which results in declined wetland function.

Water Quality

Water quality is assessed by comparing existing conditions (State Water Quality Category 1-5 which are described below and shown in Table 30) with desired conditions that are set by the States under authority of the Clean Water Act. Water quality standards are based on types of uses by people and wildlife[32]. Based on these state water quality categories, any stream listed as Category 5 or Category 4 in the watershed was identified as being highly departed from reference conditions. Non-listed streams or Categories 1-3 streams were identified as having low departure and are considered to meet the desired condition.

Water quality categories:

Category 5: —Impaired". The Environmental Protection Agency and State of Arizona maintains a list Category 5 waters called the 303d list that indicates waters with the most severe water quality problems. It is updated every other year and approved and supplemented by the Environmental Protection Agency. These waters are then scheduled for Total Maximum Daily Load (TMDL) assessments which contain strict discharge permit requirements to assure that any new discharges or modifications will not further degrade water quality.
Category 4: —Not Attaining" are those waters where designated use is —not attaining state water quality standards" and have past water quality impairments and current Total Maximum Daily Load plans aimed at improving water quality.
Category 3: Inconclusive. All designated uses are inconclusive. Also, any surface water not assessed due to lack of credible data may be included.
Category 2: Attaining some uses. At least one designated use assessed as _attaining' and all other uses assessed as _inconclusive'.
Category 1: Attaining all uses. All designated uses assessed as attaining.

[32] Types of uses may include: aquatic and wildlife use, full body or partial body contact, domestic water use, fish consumption, agricultural irrigation and livestock watering (ADEQ 2004).

Table 31: Current water quality and trend for monitored streams by fourth and fifth code watersheds

Fourth code watershed	Fifth code watershed	[33]Miles of Category 1, 2 and 3 Streams in Watershed	Miles of Category 1, 2 and 3 Streams within Forest boundary	Miles of Category 4 Streams/ Lakes in Watershed	Miles of Category 4 Streams/ Lakes within Forest boundary	Miles of Impaired Stream or Name of Category 5 Lakes in Watershed	Miles or Name of Category 5 "Impaired" Streams/Lakes within Forest boundary	[34]Trend from 1989 - Present
Havasu Creek	Spring Valley Wash	0	0	0	0	0	0	NA. No perennial streams
Middle Little Colorado River	Upper Clear Ck	87	55	0	0	0	0	Static
	Lower Clear Ck	0	0	0	0	0	0	No streams assessed
	Jacks Canyon	0	0	0	0	Long, Soldiers, Soldiers Annex Lakes	Long, Soldiers, Soldiers Annex Lakes	Static to downward. TMDL being developed.
Canyon Diablo	Rio de Flag	0	Waste water treatment plant	0	0	0	0	Static or no apparent trend
	Walnut Ck	0	0	0	0	Upper/Lower Lake Mary	Upper/Lower Lake Mary	Static to downward
	San Francisco Wash	3	3	0	0	0	0	NA. No perennial streams
	Canyon Diablo (Local Drainage)	0	0	0	0	0	0	NA. No perennial streams
	Kana-a Wash-Lower Little Colorado River	0	0	0	0	0	0	NA. No perennial streams
	Deadman Wash	0	0	0	0	0	0	NA. No perennial streams

[33] The water quality of streams/lakes dataset was provided by the Arizona Department of Environmental Quality (ADEQ 2004).
[34] Trend is an evaluation of ADEQ water quality data (not shown in this document) from 1989 – present (2005).

Fourth code watershed	Fifth code watershed	[33]Miles of Category 1, 2 and 3 Streams in Watershed	Miles of Category 1, 2 and 3 Streams within Forest boundary	Miles of Category 4 Streams/ Lakes in Watershed	Miles of Category 4 Streams/ Lakes within Forest boundary	Miles of Impaired Stream or Name of Category 5 Lakes in Watershed	Miles or Name of Category 5 "Impaired" Streams/Lakes within Forest boundary	[34]Trend from 1989 - Present
	Citadel Wash-Lower Little CO River	0	0	0	0	0	0	NA. No waters
Lower Little Colorado River	Upper Cedar Wash	0	0	0	0	0	0	NA. No perennial streams
	Lower Cedar Wash	0	0	0	0	0	0	NA. No perennial streams
	Haigler Creek-Tonto Creek	32	0	0	0	8	0	NA. No perennial streams
	Sycamore Ck	12	7	0	0	0	0	Static
	Grindstone Wash-Upper Verde River	31	4	0	0	0	0	Static to upward – TMDL approved and in progress
Tonto Creek	Oak Creek	97	46	2	2	50	50 miles (33 on Forest)	Downward. TMDL approved and in progress
Upper Verde River	Beaver Creek	22	20	Stoneman Lake	0	0	0	Static to Upward. TMDL approved. Not yet implemented
	Cherry Creek-Upper Verde River	34	2	29	15	0	0	Static to upward – TMDL approved and in progress
Lower Verde River	West Clear Creek	24	24	0	0	0	0	Static
	East Verde River	72	2	0	0	20	0	Static. No data
	Fossil Creek-Lower Verde River	35	26	21	7	0	0	Static to Slightly Upward. Lower Verde TMDL approved and in progress
	Total	**449**	**189**	**52**	**24**	**78**	**50 miles (33 on Forest), 5 Lakes**	

Reference Condition: Reference water quality was assumed to be sufficient to sustain ecological systems and species and be of equivalent quality as ‗attaining all uses' as intended by Arizona State water quality standards. Non-point sources of pollution such as roads, timber harvesting, extensive livestock grazing, recreation, and non-characteristic fire were neither widespread nor frequent.

Current Condition: On the Coconino National Forest, the most important non-point sources of pollution are from sediment generated from roads in close proximity to drainages.

Before the initiation of Best Management Practices, timber harvesting of ponderosa pine was a greater non-point source of sediments into adjoining stream courses than it is presently. The Forest currently implements and monitors site specific Best Management Practices for all activities with the potential to pollute Arizona's waters. Most water quality trends are considered to be static to upward, based on a number of mandatory and voluntary requirements imposed by the Arizona Department of Environmental Quality (ADEQ), including BMPs. These include water quality monitoring, implementation of Total Maximum Daily Load (TMDL) report recommendations, implementation and monitoring of BMPs for all projects that have the potential to increase non-point pollution, and state certification and mitigation of temporary point source pollution through the Clean Water Act's National Pollution Discharge Elimination System regulations. Wastewater treatment sites associated with campgrounds and administrative sites are the only potential point sources of water pollution the Forest manages at this time. Some water quality trends are static to downward, and the forest is working closely with the ADEQ in planning and implementing TMDL plans.

On the Forest, there are about 33 miles of impaired stream miles (Category 5) and 24 non-attaining stream miles (Category 4). There are also five Category 5 lakes. They are described below by watershed.

Middle Little Colorado River fourth code watershed: Three reservoir lakes in the Jacks Canyon fifth code watershed – Long Lake, Soldier, and Soldier Annex – are identified as impaired due to elevated mercury levels in fish tissue. The Forest is working with the Arizona Department of Environmental Quality to develop a TMDL plan for these three and the following two lakes.

Canyon Diablo fourth code watershed: Two reservoir lakes within the Walnut Creek fifth code watershed – Upper Lake Mary and Lower Lake Mary – are identified as impaired due to elevated mercury levels in fish tissue.

Upper Verde fourth code watershed: About 65% of the impaired stream miles in the Oak Creek fifth code watershed occur on Forest lands. Oak Creek and Spring Creek are impaired due to the presence of *Escheria coli* bacteria, which is attributed to the proximity of privately owned septic systems in certain stretches, wildlife contamination, and improper sanitary habits of swimmers during busy weekends. Exceeding *E. coli* bacteria criteria may represent a public health concern if people come in contact with the water. Although a TMDL is approved and is being implemented, ADEQ monitoring indicates that water quality in Oak Creek still remains impaired.

Three of the Upper Verde's 5^{th} code watersheds contain Category 4 (not attaining) waters. In the Oak Creek fifth code, 1.5 miles of Oak Creek on forest land is rated as a Category 4, primarily because of high levels of turbidity (total suspended sediment) that affect warm water fisheries. The turbidity is considered non-point source pollution and is likely coming from roads and hill slopes.

In the Beaver Creek fifth code watershed, Stoneman Lake is rated as a Category 4 primarily due to high nutrients, high pH, and low dissolved oxygen. About 60% of the lake is on Forest land and the other 40% is privately owned. An increase in nutrients can result in rapid growth of algae and other plants in the lake, which may result in a drop in dissolved oxygen that can be devastating to other aquatic life and sometimes leads to fish kills. A TMDL has been approved, but has not yet been implemented. In the Cherry Creek-Upper Verde River fifth code watershed, 29 stream miles in the Verde River are in Category 4, primarily due to exceedences in turbidity which affects warm water fisheries. Fifteen of these miles are on Forest lands, and the remainder is off Forest. A TMDL has been approved for this and the Lower Verde section (described below) and is being implemented.

Lower Verde fourth code: The Fossil Creek-Lower Verde River fifth code watershed includes 21 miles along the Verde River that are assessed as Category 4 for turbidity. About 15.5 miles in this stretch are a shared boundary with the Prescott National Forest and the remainder is privately owned. Exceedences in turbidity affects warm water fisheries.

The remaining streams miles on the Forest are classified as Categories 1-3 and are attaining some or all uses, or monitoring data is inconclusive.

Projected future conditions and trends: The Forest is currently working with the Arizona Department of Environmental Quality to determine the source of the mercury in the impaired lakes and to prepare TMDL plans. The trend of these lakes is projected to move towards reference conditions.

Most of the streams within the Beaver Creek and Oak Creek 5^{h} code watersheds are projected to move towards reference conditions, except for portions of the Beaver Creek watershed. Since 1994, the water quality in Beaver Creek has varied or fluctuated from non-attaining to inconclusive and is mostly impacted by disturbances on private lands. It is projected to move away from reference conditions.

In the Fossil Creek-Lower Verde 5th code watershed, elevated levels of pathogens (*E. coli*), streamside trash, and turbidity in Fossil Creek and downstream into the Verde River are predicted to increase in the near future as a result of increased recreation on Forest Service lands adjacent to Fossil Creek. Nonpoint source pollution into connected streams may continue to increase.

Aquatic species habitat

Aquatic and riparian habitat on the Coconino is limited in extent, yet provides for a wide array of aquatic and terrestrial biota. Overall, the Coconino accounts for 13 percent of the perennial streams and 15% of the stream reaches with native fish occurrences that exist on national forests in Arizona (Vander-Lee et al. 2007).

Information regarding current conditions of aquatic species came from multiple sources including species abstracts located on the NatureServe and the Arizona Game and Fish Department websites. Additional information is provided in the *Species Diversity Report* (USDA Forest Service 2009d). Aquatic species habitat is considered highly departed from reference conditions where non-native fish or aquatic species are currently present within the watershed, or where native species have been eliminated. Non-native species crossbreed with, eat, or compete with native species. Native species populations may also be significantly diminished or eliminated because they are unable to

thrive, or respond appropriately to changes in their environment. Appendix H (Table H-1) displays the currently occupied habitat and historic habitat of nonnative fish by 5th code watershed.

According to the Arizona Statewide Freshwater Assessment (Turner and List 2007), 15 native fish species have occurrences on one or more stream reaches on the Coconino NF. Table 32 lists the current and historical distribution of native fish species on the Forest by fourth and fifth code watersheds. Colorado pikeminnow populations are considered experimental, and the bonytail chub is considered extirpated. Together, these 15 species have occurrences on approximately 79% of the perennial streams miles that exist on the Forest. Seven of the 15 fish species are protected under the Endangered Species Act (ESA); the Gila chub, Gila topminnow, razorback sucker and Gila trout are listed as endangered species. The Little Colorado spinedace, spikedace and loach minnow are listed as threatened species.

Table 32: Current (C), reference (R) and introduced (I) occurrences for native fish species by watershed

Fourth code watershed	Fifth code watershed	Native fish species																			
		Colorado pikeminnow	Gila chub	Gila topminnow*	Razorback sucker	Gila trout	Little Colorado spinedace**	Loach minnow	Spikedace	Bonytail chub	Headwater chub	Roundtail chub	Sonora sucker	Bluehead sucker	Desert sucker	Little Colorado sucker	Longfin dace	Speckled dace	Current/historic numbers	Percent departure of current from historic	Number non-native fish
Middle Little Colorado River	Upper Clear Creek[35]	N/A	N/A	N/A	N/A	N/A	C	N/A	N/A	N/A	N/A	C	N/A	C	N/A	C	N/A	C	5/5	0	12
Upper Verde River	Sycamore Creek	N/A	N/A	R	R	N/A	N/A	R	R	R	N/A	C	C	N/A	C	N/A	C	C	5/10	50	5
	Grindstone Wash-Upper Verde River	C	N/A	R	C	N/A	N/A	R	R	R	N/A	R	C	N/A	C	N/A	C	C	6/11	45	13
	Oak Creek	N/A	C	R	N/A	R	N/A	R	R		N/A	C	C	N/A	C	N/A	C	C	6/9	33	13
	Beaver Creek	R	C	R	R	N/A	N/A	R	R	R	N/A	C	C	N/A	C	N/A	C	C	6/12	50	13
	Cherry Creek-Upper Verde River	C	N/A	R	C	N/A	N/A	R	R	R	N/A	R	C	N/A	C	N/A	C	C	6/11	45	13
Lower Verde River	West Clear Creek	N/A	N/A	N/A	C	R	N/A	R	R	N/A	C	C	C	N/A	C	N/A	C	C	7/10	30	13
	Fossil Creek-Lower Verde River	C	N/A	R/I	C	N/A	N/A	C	C	R	C	C	C	N/A	C	N/A	C	C	11/12	8	13
Current/historic numbers of 5th code watersheds with fish occurrences		¾	2/2	0/5	4/6	0/2	1/1	1/7	1/7	0/5	2/2	6/8	7/7	1/1	7/7	1/1	7/7	8/8			
Percentage departure of current from historic		**25**	**0**	**100**	**33**	**100**	**0**	**86**	**86**	**100**	**0**	**25**	**0**	**0**	**0**	**0**	**0**	**0**			

***** Gila topminnows probably occurred in the upper Verde (Minckley 1973, Weedman 1998, Turner and List 2007).
******Although spinedace persist in the 5th code watershed where they occurred historically, they face substantive challenges including nonnative aquatic species and fragmentation of habitat from roads and dams.

[35] Lower Clear Creek is assumed to have same current and historic distribution of fish as Upper Clear Creek; however inventory is lacking.

Historical impacts that occurred within the last hundred years or more years ago have resulted in significant impacts to aquatic communities and their watersheds that still remain today. As a result, fish populations have been reduced from large interconnected populations, to isolated populations within altered and degraded habitats. All the native fish species have lost much of their population redundancy[36] within and outside the forest.

Reference Condition: Prior to Euro-American settlement, it is assumed that only native fish species were present in their associated habitat, and nonnative aquatic species were absent. Aquatic habitat is assumed to have had all necessary components that native aquatic species needed for continued persistence. It is likely that habitat conditions changed spatially and temporally with fluctuations in weather patterns and other disturbances (droughts, floods, etc.). Surface water and riparian reference conditions are discussed in their respective sections.

Aquatic macroinvertebrate[37] species and distribution are largely unknown, but is assumed to be more extensive than currently present. However, because of legacy disturbances, such as water diversions and impoundments that include reservoirs, some watersheds, such as Upper Clear Creek, the Verde River, Beaver Creek and Oak Creek, are considered to have irreversible impacts to fish and probably macroinvertebrates. Stream channel down-cutting and lowering of the water table and the conversion of perennial streams to perennially-interrupted or intermittent streams has occurred on a wide spatial scale. Native fish did not evolve in reservoir habitats (large, still open waters), thus, the reservoirs mainly support socially desirable non-native species.

Current Condition: Within National Forests in Arizona, one-third to over half of the stream reaches with occurrences of four native fish species, and 36% of stream reaches with occurrence of six or more native fish species occur on the Coconino (Vander-Lee et al. 2007).

Ten of 14 (71%) native fish species on the Coconino have undergone declines in distribution across the Lower Colorado River Basin, with the remaining four (29%) showing slight increases (Olden and Poff 2005). The Red Rock Ranger District has significant lengths of streams with occurrences of six or more native fish species, which include the Verde River, Oak Creek, Fossil Creek, West Clear Creek and Wet Beaver Creek (Vander-Lee et al. 2007). According to the Arizona Freshwater Assessment, 14 stream reaches (ranging from less than three to 51 miles in length) on the Coconino have occurrences of native fish species, with the number of species on each reach ranging from two to eight (Turner and List 2007).

Current conditions for fisheries are summarized in Table 31 which displays the current and historic numbers of fish and departure from HRV by 5th code watershed (second to the last column). Seventy-five percent of 5th code watersheds are moderately departed from reference conditions for fisheries: Sycamore Creek, Grindstone Wash-Upper Verde River, Oak Creek, Beaver Creek, Cherry Creek-Upper Verde River, and West Clear Creek. Of the remaining twenty-five percent, Fossil Creek-Lower Verde River has low departure and Upper Clear Creek has no departure.

Changes in the PNVTs that adjoin waters that support aquatic organisms have altered successional structure, composition and cover classes, and process; which have also brought shifts in the FRCC as well. These changes increase the susceptibility of the watersheds to large scale or severe fires. In turn, the possibility of increased sedimentation and shifts in flood severity or frequency could increase. Road density has increased in the watersheds and near streams which contributes to

[36] Redundancy means having multiple distinct populations of a species, so that if a single disturbance event killed one population, the species would not go extinct.
[37] Animals without backbones that live in water, such as the immature forms of dragonflies, worms, and snails.

increased sedimentation, alter peak run off flows and increase fragmentation. Recreation tends to be concentrated in accessible areas and alter water quality, and soil and vegetation conditions in floodplains and upland terraces.

According to aquatic macroinvertebrate sampling conducted by ADEQ between 1992 and 2003, forestwide water quality trend for aquatic communities is upward for seven sites and downward for four sites, (Renner 2007). Warm water sites had a general upward trend in water quality (four out of five sites) and for cold water sites, two sites were upward and three had downward trends. Contributing factors to the trends could include flooding and drought cycles, microhabitat variations between collections and contribution from upland condition and associated runoff effects to water quality.

Projected Future Conditions and Trends: Aquatic species and habitat are projected to trend away from reference condition because:

- Current distributions and population conditions across the Forest do not provide for the resiliency necessary for the long-term persistence of most native fish and their habitats. The projected trend predicts that the Forest will lose some species as conditions in some areas continue to decline, given that both the number of species present and the extent and distribution of those species are shrinking.
- Nonnative and invasive aquatic species distribution is expected to persist or increase.
- Watersheds will continue to be influenced by PNVTs and soils that are departed from reference conditions.
- Recreation will continue at current, if not increased, levels thereby influencing water quality.

Many aquatic ecosystems have the ability to return towards proper functioning conditions given the opportunity. It is unknown if some native fish species will be able to persist long enough to allow for the restoration of historic functions and processes in their habitat.

KEY FINDINGS

Table 33 summarizes conditions of aquatic resources found within the 4th code watersheds associated with the Coconino NF. Adjustments in management may be necessary where risk of loss of sustainability is possible. Possible loss of sustainability of stream riparian condition and water quality is of particular concern in the *Middle Little Colorado River* 4th code watershed because the Forest has a greater than expected proportion of perennial stream miles, riparian acres, and seeps and springs in this watershed. There are proportionally more seeps and springs in the *Canyon Diablo* and *Lower Little Colorado River* 4th code watershed as well. The abundance and distribution of these features increases the probability that these 4th code watersheds will continue to function in a way that contributes to ecosystem diversity and resiliency over time.

Table 33: Aquatic resource conditions by fourth and fifth code watersheds on the Coconino NF

4th code watersheds	5th Code watersheds	Water Quality Departure and Trend[38]	Stream Riparian Condition Departure and Trend	Dominant Wetland Riparian Condition Departure and Trend	Percent of Current Native Fish Species Compared to Reference Conditions*
Middle Little Colorado River	Upper Clear Creek[39]	Low/Static	Moderate/Static	FAR – static	0%
	Jacks Canyon	High/Away - lakes	No streams	PFC – static	Not applicable
Canyon Diablo	Rio de Flag		No streams	FAR - static	Not applicable
	Walnut Creek	High/Away - lake	No streams	PFC – static	Not applicable
	San Francisco Wash	None	No streams	FAR –static	Not applicable
Lower Little Colorado River	Upper Cedar Wash	None	No streams	FAR – static	Not applicable
Upper Verde River	Sycamore Creek	Low/Static	Mostly Unknown	FAR – static	50%
	Grindstone Wash-Upper Verde River	Low/Static	Low/Static	No wetlands	45%
	Oak Creek	High/Static-stream	Low/Static	No wetlands	33%
	Beaver Creek	Low/Away-stream	High/Towards	PFC –static	50%
	Cherry Creek-Upper Verde River	High/Towards	Low/Static	No wetlands	45%
Lower Verde River	West Clear Creek	Low/Static	Low/Towards	PFC – static	30%
	Fossil Creek-Lower Verde River	High/Towards (Verde River) Low/Away (Fossil Creek)	Low/Away	FAR – static	8%
* All fish bearing waters contain nonnative fish and crayfish.					

All 4th code watersheds show a possible loss of sustainability due to water quality departures from reference conditions. This departure from reference condition warrants further evaluation of the level of risk to water quality, and the degree to which the Forest Service has authority to control or mitigate the sources causing the departure. The Middle Little Colorado River and Canyon Diablo 4th codes have a potential loss of sustainability because five reservoir lakes in the Jacks Canyon and Walnut Creek 5th codes are departed from reference conditions. The Upper Verde River and Lower Verde River 4th code watersheds have a possible loss of sustainability due to departures of stream water quality departures within three 5th codes: Oak Creek, Beaver Creek and Fossil Creek-Lower Verde River.

[38] Jacks Canyon, Walnut Creek, Oak Creek 5th code watersheds contain perennial waters classified as Impaired by Arizona Department of Environmental Quality

[39] Lower Clear Creek is assumed to have same current and historic distribution of fish as Upper Clear Creek however inventory is lacking.

The Middle Little Colorado River and Lower Verde River 4th code watersheds are have potential loss of sustainability due to departure or trends away from reference stream riparian condition in the Upper Clear Creek and Fossil Creek 5th codes watersheds.

Canyon Diablo 4th code watershed has possible loss of sustainability due to departures in wetland riparian condition in the Rio de Flag and San Francisco Wash 5th codes. Lower Little Colorado River and Upper Verde River 4th codes also have a possible loss of sustainability due to departures from reference wetland riparian conditions in the Upper Cedar Wash and Sycamore Canyon 5th codes respectively.

The Middle Little Colorado River, Upper Verde River and Lower Verde River 4th code watersheds show a possible loss of sustainability due to a departure in the number, composition, and distribution of fish species historically versus currently present. Departures occur in the Upper Clear Creek, Lower Clear Creek, Sycamore Creek, Grindstone Wash-Upper Verde River, Oak Creek, Beaver Creek, Cherry Creek-Upper Verde, Fossil Creek-Lower Verde River, and West Clear Creek 5th codes watersheds. This departure from reference conditions warrants further evaluation of the level of risk to these species, and the degree to which the Forest Service has the authority to mitigate or control the threats causing the departures.

The uplands within the Upper Verde River 4th code have reduced watershed condition integrity due to departed vegetation and soil conditions.

AIRSHEDS

Air Quality

This section describes air quality conditions and trends of the airsheds and of the Class I Wilderness Area (Sycamore Canyon Wilderness) that overlap the Forest. The Forest lies within two airsheds as defined by the Arizona Department of Environmental Quality (ADEQ): the Little Colorado Airshed and the Verde River Airshed.

In this report, air quality characteristics using national standards and thresholds represent reference conditions and existing monitoring data represents current conditions.

Reference conditions: Lightning caused wildfire, and Native American burning, are believed to have been quite common prior to European settlement. The Southwest leads the country in the incidence of lightning-caused fires. The Coconino National Forest contains over 1 million acres of vegetation with a natural fire return interval of less than 35 years. That translates into a conservative estimate of 73,400 acres burning annually with about 45,000 of those acres burning in low to mixed severity and the remainder burning in high severity conditions.

In the intervening decades since Native American burning and wildfires, air quality deteriorated across the U.S. as human-caused pollutants became more widespread and intensified. Deaths and illness caused by poor air quality sparked Clean Air Act legislation (CCA 85 U.S.C. 7401-7671q) in 1963 which was the first Federal legislation for air pollution control. The last major amendment to the Act was in 1990, with minor amendments up to 2004.

Air quality standards in the United States fall under the Clean Air Act (CAA). The CAA identifies the roles of Federal and State governments in maintaining healthy air quality and delegates responsibility for implementation and enforcement of CAA regulations to the states. Many states,

including Arizona, augment the regulations of the CAA with additional rules and guidelines. These standards serve as the reference point for current air quality.

Air quality standards

Particulate matter aerosols and sulfate and nitrate acidic deposition compounds serve as the primary measures of air quality, visibility and atmospheric deposition in the Southwest. Particulate matter affects human health and impairs visibility regardless of chemical species or emission sources. Acidic compounds that deposit on landscapes alter the chemistry of surface and ground waters, soils, vegetation, and cultural resources. Uncharacteristic chemical changes also affect aquatic and soil biota.

The CAA defines standards to protect human and environmental health. Areas that meet these standards are defined as ―attainment areas‖; those that do not are referred to as ―non-attainment areas‖. The CAA directs the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment.

The CAA also specifies that the Forest Service and other federal land management agencies are responsible for protecting Class I federal lands from adverse impacts created by external sources of air pollution.

The Forest Service's responsibility to meet air quality regulations requires coordination with the EPA and other air regulatory agencies (state, county, and tribal) including ADEQ. Coordination efforts involve managing and mitigating air pollution from Forest Service activities through adherence to state-specific regulations in addition to EPA standards.

The EPA has established NAAQS for six principal pollutants which are called "criteria" pollutants: Carbon Monoxide (CO), Lead (Pb), Nitrogen Dioxide (NO_2), Ozone (O_3), Particulate Matter ($PM_{2.5}$ and PM_{10}), and Sulfur Dioxide (SO_2). Descriptions for these pollutants are provided in the *Specialist Report for Air Resources* (Fitch 2007).

Each year EPA tracks the levels of these pollutants in the air and how much of each pollutant (or the pollutants that form them) is emitted from various pollution sources. Information about how the levels of pollutants have changed over time is posted on the EPA website by region, state, county and metropolitan area.

Areas of the country such as counties or municipalities that exceed the standards are placed in ―non-attainment‖ or ―maintenance‖ status. Areas that meet the standards are labeled as ―attainment‖ areas.

Air quality pollutants are monitored by Arizona Department of Environmental Quality. Table 34 lists sources of pollutants monitored by ADEQ, and identifies which pollutants are in part created by wildland and prescribed fires. Smoke, from wildfires and prescribed burning, is the Forest's primary contribution to air pollution.

Table 34: Sources of pollutants and those under control and authority of the Forest

Pollutant	Sources of pollutant	Sources under control and authority of the Forest
Carbon monoxide	Motor vehicles, wood-burning stove, fireplaces, wildland fires, prescribed fires, manufacturing	Prescribed fires conducted by the Forest. Suppression of wildland fires on Coconino NF.
Lead	Metal processing, waste incinerators, utilities, manufacturing	N/A
Nitrogen dioxide	Motor vehicles, electric utilities, other industrial, commercial, residential operations that burn fuels, wildland fires, prescribed fires.	Prescribed fires conducted by the Forest. Suppression of wildland fires on Coconino NF.
Ozone	Motor vehicle exhaust, industrial emissions, gasoline vapors, chemical solvents, natural sources.	N/A
Particulate matter	Dust, smoke from wood burning stoves, fireplaces, wildland fires, prescribed fires, other emissions	Prescribed fires conducted by the Forest. Suppression of wildland fires on Coconino NF.
Sulfur dioxide	Burning fossil fuels including coal, gasoline and diesel.	N/A

Class I Visibility

Class I federal lands include areas such as national parks, national wilderness areas, and national monuments. These areas are granted special protections against manmade air pollution under Section 169(a) of the CAA. Arizona has 12 Class I areas as shown in Appendix B. There is one Class I area that overlaps a portion of the Coconino NF to the west: Sycamore Canyon Wilderness (47,757 ac).

In 1999, EPA announced a major effort to improve air quality in national parks and wilderness areas. The Regional Haze Rule (40 CFR Part 51) (U. S. EPA 1999) calls for state and federal agencies to work together to improve visibility in all Class I areas by establishing emission reduction strategies. Particulate matter pollution is the major cause of reduced visibility (haze) in many parts of the United States. Haze is caused when sunlight encounters tiny pollution particles in the air, which reduce the clarity and color of what we see, particularly during humid conditions.

The national visibility goal is to return each Class I area to natural visibility conditions by 2064. Visibility impairment has been documented in all Class I Wilderness Areas of the Southwestern Region by ADEQ, generally due to regional haze. Regional Haze is defined as visibility impairment that is caused by the emission of air pollutants from numerous sources located over a wide geographic area. In the Intermountain West, sulfate (energy production), organics (wetlands, energy production, agriculture, landfills, wood burning), and elemental carbon (diesel engines, forest fires, prescribed burning) are the main cause of visibility impairment.

Current conditions: As demonstrated by air quality monitoring data (U. S. EPA 2007, U. S. EPA 2008), there are no _non-attainment‘ or _maintenance‘ areas for counties occupied by the Coconino.

Current conditions are below the national standards for all criteria pollutants. This means there is no departure in air quality related to airsheds associated with the Forest.

The emissions from implementing any of the prescribed burns generally meet National and State Ambient Air Quality Standards because the weather conditions under which burning occurs is selected by ADEQ, as is the size of the burn area on any given day. The Arizona Department of Environmental Quality considers airshed impairment across northern Arizona to be low. The nearest cities that record days of moderate or unhealthy air quality are Phoenix, Arizona and Las Vegas, Nevada (105 and 165 miles respectively from the Forest).

Current and reference visibility conditions and trends are documented through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program. Visibility is the distance it is possible to see under the prevailing atmospheric or weather conditions and is measured in deciviews (dv). A deciview is a measurement of haze that gauges the impact air pollutants have on visibility. Zero deciviews represent clear conditions with no visibility impairment. Table 35 displays the baseline visibility (reference and current) and desired conditions (2064) for Sycamore Canyon Class I area.

Table 35: Baseline conditions and projected 2064 natural conditions for Sycamore Canyon Class I Wilderness

Class I Area	Baseline data		2064 as measured by deciview
	Measured by deciview	Years	
Sycamore Canyon Wilderness	15.2 dv	2001-2004	6.96 dv

Source: IMPROVE (Colorado State University 2006)

Projected Future Conditions and Trends: Since ADEQ regulates the size and conditions under which prescribed burning are allowed, resulting emissions are projected to remain within legally acceptable limits.

Currently, however, there is a measurable difference between baseline visibility conditions (reference) and natural visibility conditions (desired future goal in 2064). If Regional Haze Rule and State Implementation Plan conditions are met, visibility conditions within Arizona Class I areas will improve. By 2064, visibility on the 20% average worst days should improve to 6.96 dv for the Sycamore Canyon Wilderness.

Pollutants that contribute to visibility impairment also contribute to atmospheric deposition and other ecosystem effects. The National Atmospheric Deposition Program (NADP) network contains nitrate and sulfate data for the Petrified National Park site, located approximately 33 miles at its closest point northeast of the Coconino. Nitrate and sulfate are acidic compounds that precipitate out of air contaminated with nitrogen dioxide ($NO_{2)}$ and sulfur dioxide ($SO_{2)}$ aerosols. For 2005, the precipitation-weighted mean concentration was 1.15 mg/liter for nitrate and 0.90 mg/liter for sulfate (NADP/NTN 2006). To reach the milestone target for the year 2018, sulfur dioxide emissions would need to be reduced by 36% and nitrogen dioxide emissions by 16% in Arizona (Fitch 2007).

In general, wet sulfate deposition is stabilizing in the west but wet nitrate deposition is increasing. At some NADP sites, nitrate concentrations are increasing, but sulfate concentrations are more

stable. If visibility conditions are improved, then atmospheric deposition levels should also decline (Fitch 2007).

KEY FINDINGS

On the Coconino, fire management has the most notable activities (planned and unplanned ignitions) that involve air quality. The level of fire activity on the Forest varies annually. About 95,402 acres have burned since 1988 on the Coconino as a result of wildfire activity (unplanned ignitions). Prescribed fire activity (planned ignitions) averaged 12,680 acres annually over the last five years and 9,911 acres annually over the last 19 years.

Air quality resulting from unplanned ignitions is monitored by ADEQ for potential human health impacts using data recorders located in several local communities including Flagstaff. Smoke advisories may be issued by ADEQ during a fire incident to affected communities and smoke sensitive groups as necessary.

All federally managed lands and all state lands, parks, and forests are under jurisdiction of ADEQ in matters relating to air pollution from prescribed burning (planned ignitions). To minimize air pollution and smoke impacts, the Coconino works with ADEQ Air Quality Division and follows Arizona's Forest and Range Management Burn Rule (A.R.S. 18-15-1500). The Coconino also employs emission reduction techniques to reduce emission and smoke impacts to Class I areas in accordance with the ADEQ smoke management program. Since ADEQ limits total acres burned per day per airshed, daily emissions from prescribed-burning do not accumulate to exceed air quality standards.

These mitigations assure that air quality standards are maintained and visibility conditions are trending towards desired conditions. Under current management, airsheds that involve the Coconino are functioning and will continue to function in a way that contributes to ecosystem resiliency and diversity over time.

THE SOUTHWEST AND CLIMATE CHANGE

The state of knowledge needed to address climate change at the Forest scale is still evolving and has many uncertainties. Most global climate models are not, yet, precise enough to apply to land management at the eco-regional or Forest scale. This limits regional and forest-specific analyses of potential effects from climate change. Additionally, there have been unprecedented socio-economic pressures on ecosystems over the past 200 years which has increased the unpredictability of future environmental change (Millar et al 2007). However, there are a number of efforts currently underway to apply projections of various climate models (Global Circulation Models and General Circulation Models (GCMs)[40]) to sub-regional scales.

At a more regional scale, studies of ancient southwestern climate may provide at least a limited historical ecological context for ecosystem variability and climate change. Such studies can provide a limited range of knowledge about past climate change, strengthening or weakening El Niño or La

[40] GCMs are complex mathematical models that simulate the interactions of atmosphere, oceans, land surface and ice, and take into account incoming and outgoing energy
(see http://en.wikipedia.org/wiki/General_circulation_model or wiki/Climate_model)

Niña events[41], patterns of precipitation, drought severity, and changes in vegetation patterns (Swetnam and Betancourt 1997, Swetnam *et al* 1999). A recurrent trend in the literature suggests that predicting the future effects of climate change and subsequent challenges to land management in the Southwest remains inexact, and will no doubt require a combination of approaches.

Current Conditions and Future Trends

Currently there appears to be broad agreement among climate modelers that the Southwestern United States is experiencing a drying trend that will continue well into the later part of 21st century (Sprigg et al 2000). Regional drying and temperature trends have occurred twice during the twentieth century (e.g., 1930s Dust Bowl and the 1950s Southwest Drought) and may have been even more severe during what is known as the Medieval Climate Anomaly, an interval of warm, dry conditions with regional variability from A.D. 900 to 1350 (Hughes and Diaz 1994). According to model scenarios, the slight warming trend observed in the last 100 years in the Southwest may continue into the next century, with the greatest warming to occur during winter. These climate models depict temperatures rising approximately 4º to 5º F (~2º to 3º C) by 2030 and between 7º and 12º F (4º and 7º C) by 2090 (Seager *et al* 2007). This trend would increase pressures on the region's already limited water supplies, as well as increase energy demand, alter fire regimes and ecosystems, create risks for human health, and affect agriculture (Swetnam and Betancourt 1997, Sprigg et al 2000).

Effects to Ecosystems

Climate may influence the distribution and abundance of plant and animal species through changes in resource availability, fecundity[42], and survivorship. Natural disturbances having the greatest impacts on forests include insects, diseases, introduced species, fires, droughts, landslides, windstorms and ice storms. Climate variability and changes can alter the frequency, intensity, timing and spatial extent of these disturbances. Many potential consequences of future climate change are expected to be buffered by the resilience of forests to natural climatic variation. Literature suggests that new disturbance regimes under climate change are likely to result in significant perturbations to National Forest lands, with lasting ecological and socioeconomic impacts (National Assessment Synthesis Team 2000, USDA Forest Service 2005a). The potential ecological implications of climate change trends in the Southwest indicate:

- More extreme disturbance events, wildfires, intense rain and wind events, etc. (Swetnam *et al* 1999).
- Greater vulnerability to invasive species, including insects, plants, fungi, and vertebrates.
- Long-term shifts in vegetation patterns (Westerling *et al* 2006, Millar *et al* 2007).
- Cold-tolerant vegetation moving upslope or disappearing in some areas. Migration of some tree species north of their existing range (Clark 1998, Thompson et al 2003).

Climate models suggest the reduced precipitation could act as a limiting factor to overall forest productivity (USDA Forest Service 2005a).

- There are already observed shifts in the timing of snowmelt in the American West, which, along with increases in summer temperatures, have serious implications for the survival of

[41] Warming in the tropical Pacific Ocean that results in flooding, drought, or other major weather disturbances through different parts of the world is called El Niño. Increased cooling in the same part of the Pacific results in La Niña which can produce the opposite results of El Niño.

[42] Numbers of young produced during the course of an organism's life.

fish species and may challenge efforts to reintroduce species into their historic range (Joyce *et al* 2007, Millar *et al* 2007).
- Increasing temperatures, water shortages, and changing ecological conditions will likely affect biodiversity and put pressure on wildlife populations, distribution, viability, and migration patterns.

Effects to Water Yield and Use

Development in the Southwest has been primarily dependent upon technology to deliver this vital resource. For example, in the Forest Service's Southwestern Region, 13 municipal watersheds in New Mexico and 19 municipal watersheds in Arizona are located on National Forest administered lands. Additionally, the locations of most snow pack and upland reservoirs are on National Forests in the Southwest (Smith *et al* 2001, State of New Mexico 2005).

- Some studies predict water shortages and lack of storage capabilities to meet seasonally changing river flow, transfers of water from agriculture to urban uses, and other critical impacts (Barnett *et al* 2008).
- There has been a decreased amount of water used by agriculture, as Arizona's booming populations demand more water for municipal and other uses (Lenart 2007). This has been an on-going trend, and could affect future agricultural uses.
- High precipitation, occurring after extended drought, may increase the number and severity of floods; and accelerate rates of soil erosion. The timing and extent of increased rainfall will play a key role in determining the degree to which people and the environment are affected (Swetnam and Betancourt 1997, Swetnam *et al* 1999, Lenart 2007).

KEY FINDINGS

The state of knowledge needed to address climate change within the Southwest is still evolving and has many uncertainties. Detailed information is lacking at the Forest scale to assess what ecosystem characteristics have declined, are at risk, or are otherwise inherently vulnerable to change due to the effects of past, current, or future climate change. As such, this topic is not addressed in any further detail in this ecosystem sustainability report.

CHAPTER 3: SPECIES DIVERSITY

General approach

Species diversity is used in conjunction with ecosystem diversity to help formulate plan components for ecological sustainability (USDA Forest Service 2006). In the revised Forest Plan, the combination of plan components for ecosystem diversity and plan components for species diversity will help provide appropriate ecological conditions for all species that have been identified as federally listed species or Forest planning species. This chapter summarizes the process used to establish which species and/or risk factors should be addressed by the revised plan. Those species not taken care of by components that address ecosystem diversity may require new or revised Forest Plan components to provide sustainable species diversity.

The Species Diversity Report (USDA Forest Service 2009d) and its associated ACCESS database, describe the species lists identified in the planning process, as well as the method of information collection and evaluation of habitat associations, and species threats and risks. These elements are summarized in this chapter.

Species Lists

Identification of species to be considered was conducted using the following criteria (in order to be considered, a species range needed to include the Forest):

- Species already federally listed under the Endangered Species Act (ESA). The Forest's list of threatened and endangered species was used with consideration of "accidentals"[43], and historical versus current distribution;
- species identified as proposed and candidate species under the Endangered Species Act,
- Species ranked G-1, G-2 and G-3[44] by NatureServe (NatureServe 2007-2009) with additional direction (USDA Forest Service 2008c,
- Subspecific taxa ranked T-1, T-2 and T-3[45] by NatureServe;
- species that have been petitioned for federal listing and for which a positive ―90 day finding" has been made,
- Species that have recently delisted, including those delisted within the past five years and other delisted species for which regulatory agency monitoring is still considered necessary;
- Species ranked S-1, S-2, N-1, N-2 by NatureServe (NatureServe 2007-2009);
- State listed threatened and endangered species (Arizona has none),
- Species identified as species of conservation concern in Arizona Comprehensive Wildlife Conservation Strategy (AZGFD 2005), and
- Species on the U.S. Fish and Wildlife Birds of Conservation Concern National Priority List. (U.S. Fish and Wildlife Service 2002 and 2008).

Region 3 Sensitive Species not meeting any of the criteria above.

Some factors that suggested further consideration were:

- species habitat or population has declined significantly in the Forest
- species and its habitats are not well-distributed in the Forest

[43] Species that do not occur in a region under normal circumstances (Sibley 2001).
[44] Ranks reflect condition of species across its range at the global scale (G). G1 = critically imperiled, G2 = Imperiled, G3 = Vulnerable, G4 = Apparently secure, G5 = Secure (NatureServe 2007-2009).
[45] T refers to subspecies, varieties, or other designations below the level of species.

- species population numbers are low in the Forest.
- species is dependent on a specialized habitat or one that is limited in the Forest
- there is some imminent threat to the species
- species habitat or population is not generally secure on the Coconino and Coconino lands act as an important refuge
- species is of public interest
- species poses a threat to ecosystem or species diversity

Information collection

Information was collected to make an assessment of species occurrence in the planning area and to categorize species.

Sources of information included, but were not limited to:

- Regional Foresters Sensitive Species List (Forest Service 2007),
- feedback from a Species Diversity Workgroup[46],
- State Heritage Data Management System,
- Breeding Bird Atlas (Corman and Gervais-Wise 2005)
- Arizona Rare Plant Task Force,
- Museum of Northern Arizona (Stevens 2007),
- taxonomy books, field guides, journals, various publications, on-line herbaria,
- species listing or ranking within various strategies, agreements and lists[47] and
- Local, regional or national experts for various plant taxa.
- U.S. Fish and Wildlife Service and the Arizona Game and Fish Department were additionally contacted regarding information about future plans to supplement, introduce or re-introduce species on or adjacent to the Coconino National Forest within the next 5-10 years.

Screening of species

Screening of T&E and forest planning species used the criteria below to determine if species required further consideration in the species evaluation and revised Forest Plan. The criteria were used to drop species from further consideration.

- there were no known occurrences or suitable habitat of the species on the Forest,
- species are secure in the plan area,
- species are not affected by management or potential plan components

[46] Species diversity working group participants included: representatives from the Forest Service, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, Grand Canyon Wildlands Council, National Park Service, The Nature Conservancy, Sierra Club, Northern Arizona Audubon Society and others.

[47] Arizona Partners in Flight Bird Conservation Plan (Latta et al. 1999), Partners in Flight (Rich et al 2005), Statewide Conservation Agreement for native fish (AZGFD 2006), Western Bat Working Group priorities, Arizona Bat Conservation Strategic Plan (Hinman and Snow 2003), Arizona's native plants Administrative Rules and Laws, and the influence a species has on an ecosystem e.g. keystone or strongly interactive species (Mattson et al. 2005, Soule et al. 2005, Ripple and Beschta 2006) and invasive species.

- enough information is known to complete a credible assessment.

Results of Screening

About 1,845 species were examined as possible species for further evaluation (Appendix A). Seventy-seven percent of these species were not considered further because their home range did not overlap the Forest; because there was insufficient information available to determine occurrence on the Forest; because of taxonomic uncertainties; or they did not meet the above criteria for consideration as a Forest planning species (USDA Forest Service 2006b and 2008c). This resulted in an *initial list* of 430 species. Information was collected on the initial list species considering the criteria above, resulting in a *potential list* of 399 species. The potential list was additionally refined based on whether the species were considered secure in the plan area or affected by management. This refinement or screening process resulted in 190 species being considered for further analysis: 18 T&E and 172 Forest planning species.[48] They are listed in Appendix B.

Habitat Associations and initial species groups

Species cannot be managed separately from their habitats. Habitats are affected by management and other actions that occur within them, and in some cases, by actions occurring outside of them. One assumption used in this analysis was that by providing habitats and key habitat attributes, managers would provide for a wide array of associated species.

Species from the screened list were placed into the following groups by similarities in habitat requirements to streamline the analysis (USDA Forest Service 2006).

- Species linked with terrestrial or aquatic habitat associations and the mix of ecosystem diversity characteristics within that association.
- Species grouped on other factors (special features) and
- Other species

More detailed information is located in the Species Diversity Report (USDA Forest Service 2009d).

A list of species and the PNVTs (and water) they were linked to is located in Appendix G. Table 36 shows the number of species by category associated with PNVTs, water, and 4th code watersheds. *Ponderosa Pine*, *Water*, and the *Upper Verde River 4th code* watershed have the highest number of species.

[48] Bald eagles are counted twice because there are listed and non-listed populations on the Coconino NF.

Table 36: Summary of PNVTs, water, 4th code watersheds and species status

Habitat	T&E	Forest planning species
Cottonwood Willow Riparian Forest	3	12
Desert Communities	1	13
Semi desert Grassland	0	16
Mixed Broadleaf Deciduous Riparian Forest	1	18
Great Basin Grassland	1	7
Interior Chaparral	0	3
Piñon-Juniper Evergreen Shrub	0	21
Piñon-Juniper Woodland	0	24
Wetland / Cienega	0	8
Ponderosa Pine	1	53
Montane Willow Riparian Forest	0	9
Dry Mixed Conifer	1	21
Montane / Subalpine Grassland	1	14
Spruce fir	0	17
Alpine Tundra	1	13
Water	9	39
Aquatic species[49]		
Middle Little Colorado River	2	6
Lower Little Colorado River	0	0
Canyon Diablo	0	1
Upper Verde River	3	32
Lower Verde River	6	11

Species linked with ecosystem diversity characteristics

If a group of species is associated with a specific habitat, then the risk to those species were assumed to be the same as the risks for that particular habitat or ecosystem characteristic. This is discussed further in the species risk section in the next chapter. Although some species are associated with structural components of PNVTs such as snags, downed logs, specific tree sizes,

[49] The number of species associated with water does not equal the number of aquatic species because several species are associated with more than one watershed. The number includes species currently known plus those known to occur in watershed historically.

openings, and shrubs, these components are considered part of a PNVT functioning within the range of historic variability, and as such, are subject to the same threats as the PNVT.

Species grouped on other factors

Special features were used to group species around key habitat elements that are finer or larger than landscape scale. While most of these special features were not analyzed as part of the ecosystem diversity analysis, they are still managed under the Forest Plan. Categories of species associated with special features are listed in Table 37. Threats and risks to the species are the result of the management of those features. The *Rocks* category has the highest number of species.

Special features are:

- *Rocks*: Rock features include canyons, cliffs, talus, and other rocky surfaces.
- *Water features*: Water features include hanging gardens, ephemeral pools, seasonally wet areas, wet ground, springs, seeps, and stock tanks.
- *Human made structures*: Bridges, buildings, archaeological sites, railroad beds.
- *Soil type*: Soils with different parent materials or mineral concentrations, such as limestone, sandstone, or basalt.

Table 37: Summary of species groups and status of associated species

Group	T&E species	Forest planning species
Rocks	1	24
Water feature	0	16
Human made structures	0	6
Soil type (Basalt, cinders)	0	11
Soil type (Calcareous, alkaline, gypsum)	0	7
Soil type (dolomitic limestone and limestone)	1	13
Soil type (Sandstone)	0	6
Soil type (Verde Formation)	1	4

Some species are associated with PNVTs, as well as special features. Therefore, the number of species associated with PNVTs, plus the number of species associated with special features, total more than 100% of the species carried forward for further analysis. An example is the Mexican spotted owl, which nests in Dry Mixed Conifer and Ponderosa Pine PNVTs and in canyons; and another example is a plant that is associated with specific soil types and PNVTs.

Other species

Invasives: Twenty-eight animal species were identified as invasives, nonnative or threats to species or ecosystem diversity (Appendix H). They are treated as threats or disturbances in this report. Invasive and nonnative plant species (with the exception of annual grasses) are addressed in the Weeds Report (USDA Forest Service (2008).

Species using variety of habitats: Mexican gray wolves, California condors, and mountain lions occur within a variety of habitats and are not associated with specific PNVTs or special features. They were analyzed individually for threats and risks.

KEY FINDINGS

Table 38 summarizes the number of species carried forward for further analysis in plan revision by taxonomic group and status.

Table 38: Number of T&E and Forest planning species by taxonomic group and status

Status	Birds	Fish	Invertebrates	Mammals	Plants	Reptiles and Amphibians	Total
T&E	5	8	0	2	2	1	18
Forest planning species	13	7	33	16	96	7	172
Total	**18**	**15**	**33**	**18**	**98**	**8**	**190**

CHAPTER 4: RISKS TO ECOSYSTEMS AND SPECIES

This chapter summarizes risks to ecosystems and to species. Risk is defined as the likelihood and potential severity of a negative outcome, at the ecosystem level, from a threat.

ECOSYSTEM RISK

Risk to ecosystem diversity characteristics (e.g., composition, structure, process) was assessed by:

- looking at the departures from reference conditions, and trends under current management, that were identified in the first part of this report;
- identifying threats that contribute to the risk, and
- determining which threats are under agency authority to control or mitigate.

The following model (Figure 7) was used to categorize risk to PNVTs relative to likelihood and severity using departures in vegetation, fire regime condition class, and soil. The combinations of severity and likelihood result in different categories of risk relative to the ecosystem sustainability of PNVTs and potential needs to further evaluate threats or current management.

		Likelihood		
		No Trend or **STATIC** relative to reference condition	Trend **TOWARDS** Reference Condition	Trend **AWAY** from Reference Condition
Severity	Substantial Departure from Reference Conditions	Legacy of past management OR static deviation from ongoing activities. Evaluate system reversibility, threats. (A)	Risk addressed. Continue current management and identify restoration opportunities. (B)	Potential for high risk. Evaluate system reversibility and threats. (C)
	No Substantial Departure from Reference Conditions	Low risk. Continue current management. (D)	No Deviation. No Risk. Continue current management. (E)	Potential risk. Evaluate magnitude of future deviations, threats and reversibility. (F)

Figure 7: Contributions of likelihood and severity to categories of risk

The findings of this risk assessment follow. A summary of PNVT conditions, associated species and risk categories are displayed in Table 39. No PNVTs fit Categories D or E.

Category A: *Cottonwood Willow Riparian Forest*, *Mixed Broadleaf Deciduous Forest, Wetland Cienega,* and *Montane Willow Riparian Forest* exhibit risks associated with past management or have static deviations from ongoing activities. *Mixed Broadleaf Deciduous* has a moderate vegetative departure from reference conditions. This departure is likely to persist because the PNVT is expected to continue to be affected by flooding and drought[50]. *Mixed Broadleaf*

[50] Midscale trend analysis was not conducted due to the small extent of the PNVT.

Deciduous Riparian is found in two sections and four 5th code watersheds. *Wetland Cienega* is found in one section and eight 5th code watersheds. *Montane Willow Riparian Forest* is mainly found in one section and three fifth code watersheds. The distribution of these PNVTs in several fifth codes suggests that the PNVTs are less vulnerable to a single catastrophic event i.e. a single wildfire burning 100% of the PNVT on the Forest. Further evaluation of system reversibility and threats is needed for all three PNVTs, as is special consideration for listed species in *Mixed Broadleaf Deciduous Riparian*.

Category B: The *Spruce-fir* PNVT shows measurable departure in vegetation condition and fire regime condition class. Spruce-fir is trending towards vegetative reference conditions. This PNVT is too small to determine a trend in fire regime using Forest fire data. It is located in one section and the majority is in two 5th code watersheds (but are adjacent to each other) so is vulnerable to loss from single catastrophic event. However, although it can experience some low severity fires, generally this PNVT has a fire interval greater than 200 years with more than 75% of the overstory replaced. Stand replacing fire is within HRV.

Great Basin Grassland shows a measurable departure in in fire regime condition class primarily due to lack of fire in adjacent PNVTs and is trending towards soil reference conditions. It is found in two sections and four fifth code watersheds suggesting that it less vulnerable to a single catastrophic event.

Risk is addressed for both of these PNVTs. Continue current management and identify restoration opportunities.

Category A/C: Departures and known trends of *Desert Communities* suggest that risk is primarily associated with the legacy of past management; or risk has a stable deviation from ongoing management. Vegetation trends are unknown, so potential for high risk (Category C) may also be possible. This PNVT is too small to conduct midscale trend analysis. It is found in one section and seven 5th code watersheds which suggest that the PNVT is less vulnerable to a single catastrophic event. In either case, further evaluation of system reversibility and threats is needed, as is special consideration for listed species.

Category C: *Semidesert Grassland, Montane Subalpine Grassland*, *Ponderosa Pine, Dry Mixed Conifer, Interior Chaparral, Piñon Juniper Woodland and Piñon Juniper Evergreen Shrub* PNVTs have the potential for high risk because one or more characteristics are substantially departed from reference and, under current management, are trending away from reference conditions. System reversibility and threats need to be evaluated. Special consideration is needed for associated listed species in *Cottonwood Willow Riparian, Montane Subalpine Grassland, Ponderosa Pine,* and *Dry Mixed Conifer.*

Category F: *Alpine Tundra* has potential risk due to low departure and its trend away from reference condition. Further evaluation of future departures, threats, and reversibility is needed. It is found in one section and in three 5th code watersheds (but all adjacent locations) so is vulnerable to loss of sustainability. Special consideration is needed for associated listed species.

Table 39: Summary of departures and trends of multiple ecological characteristics, associated species, risk category, and findings by PNVT

PNVT*	Vegetation departure and trend	Fire regime condition class departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	Number of species that were carried forward by category	Risk category	Risk assessment findings and recommendations
Major PNVTs > 1% of Forest						
Semi-Desert Grasslands	H-Away	M-Away	H-Static (72%)	16 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Great Basin Grassland	L-Unknown	High-Unknown	H-Towards (87%)	1 T&E & 7 Forest planning species	B	Continue current management and identify restoration opportunities.
Interior Chaparral	L-Static	M-Away	L-Static (<1%)	3 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Piñon Juniper Evergreen Shrub	M-Away	M-Away	M-Static (61-66%)	21 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Piñon Juniper Woodland	M-Static	H-Away	M-Static to Away (10%)	24 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Montane Subalpine Grasslands	L-Unknown	H-Away	M-Static (<5%)	1 T&E and 14 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.

Ponderosa Pine	H-Away	H-Away	L-Static (18%)	1 T&E and 53 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Dry Mixed Conifer	H-Static	H-Away	L-Static (46%)	1 T&E and 21 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
PNVT	**Vegetation departure and trend**	**Fire regime condition class departure and trend**	**Soil productivity departure and trend (% severe erosion hazard)**	**Number associated species**	**Risk category**	**Risk assessment findings**
PNVTs < 1% of Forest						
Cottonwood Willow Riparian	M-Unknown	Not key process in this system	H - Static (97-98%)	3 T&E and 12 Forest planning species	A	Potential for high risk. Evaluate system reversibility and threats.
Mixed Broadleaf Deciduous Riparian	M-Unknown – likely to persist	Not key process in this system	L-Static (1-2%)	1 T&E and 18 Forest planning species	A	Legacy of past management OR stable deviation from ongoing activities is suggested. Evaluate system reversibility and threats.
Wetland/Cienega	L-Unknown	Not key process in this system	M-Static (98%)	8 Forest planning species	C	Potential for high risk. Evaluate system reversibility and threats.
Montane Willow Riparian	M-Unknown	Not key process in this system	L-Static (7%)	9 Forest planning species	A	Legacy of past management OR stable deviation from ongoing activities is suggested. Evaluate system reversibility and threats.
Desert Communities	H-Unknown	Not key process in this system	H - Static (99%)	1 T&E and 13 Forest planning species	A/C	Legacy of past management OR stable deviation from ongoing activities is suggested however there may be potential for high risk due to unknown vegetative trend. Evaluate system reversibility and threats.

Spruce Fir	M-Towards	M-Unknown	L-Static (79%)	17 Forest planning species	B	Continue current management and identify restoration opportunities.
Alpine Tundra	Low-Away	Not key process in this system	L-Static (100%)	1T&E and 13 Forest planning species	F	Potential risk. Evaluate magnitude of future deviations, threats and reversibility.
* Shaded PNVTs: Forest has high contribution to sustainability. Unshaded PNVTs: Forest has moderate contribution to sustainability.						

The next step in risk assessment is to identify threats that contribute to the risk identified above, and determine which threats are under agency authority to control or mitigate. Threats were identified that were specific to the risk associated with the departure from reference conditions for ecosystems. Threats were then screened to determine whether they were under agency management authority, i.e., whether the Forest makes the decision to perform that action or whether the Forest regulates or mitigates the effects of the action. Threats under agency management authority were considered further in the risk assessment to arrive at the identification of ecosystems at risk that the Forest can influence. Threats outside agency management authority were not considered further. Screened threats were evaluated for potential ecosystem response if the threat was eliminated or reduced. Threats that were considered are listed in Appendix I. These steps resulted in identification of ecosystem characteristics at significant risk due to specific management activities that are under agency authority to control or regulate and would be responsive to Forest Service management.

The ecological systems on the Forest are currently subject to threats that were not present at reference conditions, at least not at current and projected levels. These threats include air and water pollution, habitat fragmentation, changes in land use, invasive plant, animal and pathogen species, and altered fire regimes. In addition to these threats, future climate may be more variable and extreme than in previous time periods. Current ecosystems and species may be challenged in dealing with the combination of natural and human threats, as well as a changing climate (Millar et al. 2007).

Tables 40-42 show the most prominent threats to terrestrial ecosystem diversity characteristics by PNVT and whether or not they are considered under agency management authority. *Managed grazing* is not considered a threat to PNVTs when conducted under current NEPA, Best Management Practices are implemented, and the Annual Operating Plan is current. Managed grazing is grazing managed to meet desired conditions in Forest Plan or subsequent NEPA. Grazing modifies the structure and composition of herbaceous and woody understory and influences soil condition and productivity. Soil condition and productivity in *Desert Communities, Semi-Desert Grassland, Great Basin Grassland,* and montane portion of *Montane Subalpine Grassland* have been impacted by historical grazing and are responding slowly to improved grazing strategies. *Unmanaged livestock grazing* is grazing that is not managed to meet desired conditions. Soil condition and productivity in *Wetland Cienega* have been impacted by historical grazing and are responding slowly to improved grazing strategies. Nine percent of the wetland acres (38% of the wetlands) are not functioning properly. The remaining wetlands are functioning properly. *Unmanaged livestock grazing* is grazing that is not managed to meet desired conditions. It is not considered a threat to PNVTs because there is no consistent pattern of livestock over utilization on an allotment (Forest Service 2007).

Table 40: Primary threats to forest and woodland PNVTs on Coconino NF (Piñon Juniper Evergreen Shrub and Woodland, Ponderosa Pine, Dry Mixed Conifer and Spruce-Fir)

Primary Threats	Description of threat
Under agency management authority	
Fire exclusion	Fire exclusion lengthens fire return intervals which can result in denser vegetation, loss of age class diversity, high canopy cover, loss of early succession species, and reduction in herbaceous understory in these types.
Uncharacteristic fire	Fire burning at a severity, frequency, or scale outside historic range of variability which can result in loss of existing vegetation, soil damage, and erosion.
Nonnative invasive plant species	Nonnative invasive plants are highly competitive and have few if any threats. Once established, they can replace native species and disrupt ecological processes including soil stability, fire return intervals, and hydrologic regimes. Primarily a threat in *Ponderosa Pine* because the abundance, diversity, type, and distribution of invasive nonnative plants is greater than in other PNVTs. Low to negligible landscape threat in other types.
Outside agency management authority	
Drought	Drought is a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area. Loss of vegetation can occur. Trees can be more susceptible to insect and disease as a result.
Excessive wildlife herbivory	Excessive wildlife herbivory is herbivory at levels that prevent the attainment of desired conditions in the Forest Plan. Herbivory at this level can substantially modify the structure and composition of herbaceous and woody understory and influence ecosystem processes such as properly functioning soil. Forest Service is not responsible for management of wildlife populations. Greatest impacts occur in *Ponderosa Pine* on early succession species such as aspen.
Insect, disease, pathogens, parasites	Insect, disease, pathogens and parasites are part of natural disturbance regime and under the authority of the Forest only to a limited and often indirect extent. The Forest influences vegetative conditions so that areas are more resilient to outbreaks. Management options are fewer in areas designated as wilderness.
Nonnative invasive animal species	Invasive animal species influence and can significantly disrupt the composition and structure of ecosystems as well as natural processes. This threat is specific to *Spruce-Fir* because of the presence of an exotic spruce aphid. Diminished representation of spruce may occur in the future as a result.

Table 41: Primary threats to shrub and grassland PNVTs on Coconino NF (Desert Communities, Interior Chaparral, Semi-Desert, Great Basin and Montane Subalpine Grasslands, and Alpine Tundra)

Primary Threats*	Description of threat
Under agency management authority	
Fire exclusion	Facilitates invasion of shrubs and trees in grasslands and reduction in herbaceous understory. Fire primarily enters grasslands from adjacent PNVTs. Shift towards shrubs and trees may be irreversible in about 30% of *Semi-Desert Grassland*. Fire is not a key ecological process in *Desert Communities* and *Alpine Tundra*.
Uncharacteristic fire	Fire burning at a severity, frequency, or scale outside historic range of variability. Primarily threat in *Desert Communities* because of the potential for spread and establishment of invasive grasses which can promote a fire return interval outside HRV. *Semi-Desert Grassland* and *Interior Chaparral* are vulnerable to more severe fires because of shifts to older age classes or more shrubs and trees.
Nonnative invasive plants species	Nonnative invasive plants are highly competitive and have few if any threats. Once established, they can replace native species and disrupt ecological processes including soil stability, fire return intervals, and hydrologic regimes. Primarily a threat in *Desert Communities* and *Semi-Desert Grassland (*invasive grasses), as well as *Great Basin and Montane Subalpine Grasslands.* Low to negligible landscape threat in *Interior Chaparral and Alpine Tundra.*
Off Highway vehicles	Off Highway vehicle use in *Desert Communities* causes soil and vegetation loss because of the erodible nature of the soils. Recovery is very slow due to the arid nature of this vegetation type.
Outside agency management authority	
Drought	Drought is a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area. Significant loss of vegetation can occur.
Changes in weather patterns	In *Alpine Tundra*, there is a shift towards increased meadows and fewer talus slopes due to changes in weather patterns.
Excessive wildlife herbivory	Excessive wildlife herbivory is herbivory at levels that prevent the attainment of desired conditions in the Forest Plan. Herbivory at this level can substantially modify the structure and composition of herbaceous and woody understory and influence ecosystem processes such as properly functioning soil. Primarily a threat in the montane portion of *Montane Subalpine Grasslands* and *Great Basin Grasslands.* Wildlife use is generally concentrated in meadows especially when adjacent to water and suitable cover. Forest Service is not responsible for management of wildlife populations.

Table 42: Primary threats to riparian PNVTs on Coconino NF (Cottonwood Willow Riparian, Mixed Broadleaf Deciduous Riparian, and Montane Willow Riparian Forests, and Wetland Cienega)

Primary threats*	Description of threats
Under agency management authority	
Fire exclusion in adjacent PNVTs	*Montane Willow Riparian* occurs in small scattered patches on the Forest, and thus is influenced by surrounding PNVTs more so than PNVTs that occur in larger patches. Fire exclusion in adjacent PNVTs encourages the establishment of conifers and increases canopy which reduces deciduous species in this riparian PNVT. This also occurs in *Mixed Broadleaf Deciduous Forest.*
Uncharacteristic fire	Uncharacteristic fire is fire burning at a severity, frequency, or scale outside historic range of variability. The three riparian forest PNVTs occur in small, or linear discontinuous patches on the Forest. Consequently, adjacent PNVTs with departed fire regime condition classes can threaten structure and composition of these riparian forests. The location of *Cottonwood Willow Riparian and Mixed Broadleaf Deciduous Riparian* at the bottom of drainages makes them additionally susceptible to sedimentation and soil erosion resulting from uncharacteristic fire within their watersheds.
Nonnative invasive plants species	Nonnative invasive plants are highly competitive and have few if any threats. Once established, they can replace native species and disrupt soil stability, fire return intervals, and hydrologic regimes. A moderate threat in *Cottonwood Willow Riparian* because riparian dependent invasives will limit and eventually cause a decline in quality of native species regeneration potential. Instream flows may be reduced as a result because these nonnative woody plants draw more water out of the water table than native trees. *Mixed Broadleaf Deciduous Riparian* has a low threat because some highly invasive weeds are present as are non-native annual grasses, which could cause changes in ecosystem integrity if not controlled. *Montane Willow Riparian* is moderately threatened by introduction of weeds from adjacent PNVTs that contain higher abundance and diversity of weeds. Weed threat is low in *Wetland Cienega.*
Outside agency management authority	
Drought	Drought is a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area. As a result, loss of vegetation can occur, and trees can be more susceptible to insect and disease.
Excessive wildlife herbivory	Excessive wildlife herbivory is herbivory at levels that prevent the attainment of desired conditions in the Forest Plan. Herbivory at this level can substantially modify the structure and composition of herbaceous and woody understory and influence ecosystem processes such as properly functioning soil. Wildlife use is generally concentrated adjacent to water and suitable cover. Forest Service is not responsible for management of wildlife populations. Greatest impacts occur in *Montane Willow Riparian* on willows and *Wetland Cienega.*
Flooding	Flooding is a natural process essential for the sustainability of riparian areas. Flooding influences geomorphology of streams and structure, composition and structure of adjoining riparian vegetation. The Forest can't control the onset, location or duration of these processes, but it can influence the resiliency of ecosystems.
Insect, disease, pathogens, parasites	Insect, disease, pathogens and parasites are part of natural disturbance regime and under the authority of the Forest to a limited extent. The Forest influences vegetative conditions to a limited extent so that areas are more resilient to outbreaks. *Cottonwood Willow Riparian* and Mixed *Broadleaf Deciduous Riparian Forests* are associated with this threat, but appear to be functioning within HRV.
Water withdrawal, well pumping	Water withdrawal is under Forest control within Forest boundaries only. National and regional ground water policy directs Forest well drilling and pumping not to adversely affect connected riparian habitat and water quantity and quality. Arizona Department of Water Quality controls adjacent water withdrawal from current and new wells. Water tables are lowering because of water withdrawals adjacent to Flagstaff and Verde Valley cities which can perch affected riparian communities (primarily *Cottonwood Willow Riparian*) above available water.

PNVT Risk Assessment KEY FINDINGS

In the following paragraphs, threats under control and authority of the Forest Service are in italics. Ten PNVTs have the potential for high risk for loss of sustainability. *Semi-Desert Grassland, Great Basin Grassland, Interior Chaparral, Piñon Juniper Evergreen Shrub, Piñon Juniper Woodland, Montane Subalpine Grassland*, *Ponderosa Pine, Dry Mixed Conifer, and Montane Willow Riparian Forest* have potential for high risk because dominant vegetation or fire regime condition class are substantially departed from reference conditions and, under current management, are trending away from reference conditions or have unknown trends. Primary threats under Forest Service management authority are *fire exclusion and uncharacteristic fire*. Fire exclusion interrupts natural fire return intervals. It ultimately affects the density and structure of live and dead vegetation, overstory and understory abundance, diversity and resiliency, and soil productivity in many of these PNVTs. As density of live and dead vegetation increases, vulnerability to *uncharacteristic fire* increases.

Cottonwood Willow Riparian Forest also has the potential for high risk of loss of sustainability due to departures in vegetation and soil because of dropped water tables*, invasive plant species and recreation*. Water tables have dropped because of a legacy of water diversions that occurred historically and that were largely outside Forest Service management authority. They have also dropped in areas adjacent to Verde Valley cities as a result of groundwater pumping by municipalities. Consequently, portions of this PNVT are now perched above the water table and its long term sustainability may be in jeopardy. Riparian dependent invasive and nonnative plant species are also anticipated to cause a decline in quality of native species regeneration potential and possible reduction in instream flows. Recreation use causes vegetation and soil loss in some portions of the PNVT.

Desert Communities is at risk because of substantial departures in vegetation and soil condition. These departures plus known trends suggest that risk is primarily associated with a legacy from past management; or risk has a stable deviation from ongoing management. One current threat is *nonnative invasive plants*, especially *annual grasses***,** which can substantially alter fire return intervals and compete with native species which are not adapted to frequent fire. Another threat is *off highway vehicle travel***,** which increases erosion and subsequent loss of soil and vegetation. Historical grazing has also impacted this PNVT from which Desert Communities is slowly recovering. *Nonnative invasive plants*, especially annual grasses, are also a threat because once established; they can replace native species and disrupt soil stability, fire return intervals, and hydrologic regimes

Wetland Cienega is at risk because of high departures in soil condition and productivity, and vegetation trend is unknown. A primary threat is wildlife herbivory which is largely outside Forest Service management authority. This current threat co-exists with historical effects of managed grazing and the widespread occurrence of stocktanks that were historically built in wetlands. Current livestock grazing is not considered a threat to Wetland Cienega at the PNVT level when conducted under current NEPA, Best Management Practices are implemented, and the Annual Operating Plan is current. Managed grazing is grazing managed to meet desired conditions in Forest Plan or subsequent NEPA. Stocktanks have modified the shape, size, and depth of wetlands and attract wildlife and livestock.

Mixed Broadleaf Deciduous Riparian Forest has a legacy of past management or stable deviation from ongoing activities because of a moderate departure in dominant vegetation with an unknown trend. Primary threats are *fire exclusion and the risk of catastrophic fire in adjacent PNVTs* which could result in catastrophic fire entering this PNVT, or sedimentation and erosion. Another threat

is the presence of highly *invasive nonnative plant species* and *invasive annual grasses* which can change fire return intervals if not controlled.

Vegetative conditions for *Spruce-fir* are trending towards reference conditions, primarily due to large fires in the early 1900's. Fire regime condition class may be at risk primarily due to *fire exclusion;* however, a full fire return interval has not passed since these large fires.

Alpine Tundra has potential risk of increasing meadows and fewer talus slopes due to warming weather patterns. However, the long term trend of weather patterns is uncertain and outside the control of the Forest.

AQUATIC SYSTEM RISK

Risk assessment of aquatic characteristics follows a similar process to that described for terrestrial characteristics. Aquatic characteristics that are at risk all have moderate to high departures from reference conditions and are trending away from reference conditions or have a static trend. Characteristics trending towards reference conditions are not considered at risk. Watersheds with fish bearing streams were considered departed because they all contain nonnative fish.

Risks to *perennial streams* were based on departure of native fish, water quality, stream riparian condition, water yield (where known), and watershed condition relative to fire regime condition class by 5th code watershed.

Risks to *water quality* was based on ADEQ categories 4 or 5 (Impaired, Not Attaining, or has a Total Maximum Daily Load (TMDL) Assessment). Water quality impairments (turbidity, mercury, dissolved oxygen and nutrients) may or may not be attributable to upland soil and vegetation conditions. Categories 2 and 3 were not included because they represent _insufficient' or _inconclusive' sampling data from ADEQ.

Habitat for aquatic species was considered at risk if one or more nonnative aquatic species were present in the perennial stream.

A watershed was generally considered more severely departed if it had a high extent on the Forest; had a relatively high number of aquatic ecosystem characteristics at risk (compared to other watersheds); and had a relatively large percentage of Forest and woodland vegetation in the watershed. Table 43 displays departures and trends of aquatic ecosystem characteristics by watershed in the last five columns. It also displays the percentage of the watershed composed of forest and woodland vegetation, which have a higher risk of uncharacteristic fire than other vegetation types. *Characteristics at risk* are shaded.

Table 43: Departures and trends for multiple aquatic characteristics at risk by watersheds

4th Code Watershed	5th Code Watershed	% of Forests & Woodlands in portion of watershed that occurs on Forest	% Departure Current # Native Fish Compared to Reference	Water Quality Departure and Trend	Streamflow yield trend	Stream Riparian Condition Departure and Trend	Wetland Riparian Departure and Trend
Middle Little Colorado	Upper Clear Creek	99	0	None	No data	M/Static	No wetlands
	Lower Clear Creek	100	0	None	No data	M/Static	No wetlands
	Jacks Canyon	80	N/A	H/Static*	No data	N/A	No wetlands
Lower Little Colorado	Kana a Wash	95	N/A	None	No data	N/A	No wetlands
	Deadman Wash	88	N/A	None	No data	N/A	No wetlands
	Citadel Wash	63	N/A	None	No data	N/A	No wetlands
	Upper Cedar Wash	83	N/A	None	No data	N/A	No wetlands
	Lower Cedar Wash	100	N/A	None	No data	N/A	No wetlands
Tonto Creek	Haigler-Tonto Creek	100	N/A	None	No data	N/A	No wetlands
Canyon Diablo	Rio de Flag	96	N/A	None	No data	N/A	FAR - static
	Walnut Creek	87	N/A	H/Static*	No data	N/A	No wetlands
	San Francisco Wash	88	N/A	None	No data	N/A	PFC and FAR - static
	Canyon Diablo	75	No natives	None	No data	None	FAR - static
Upper Verde River	Sycamore Creek	81	50%	None	Static to slightly downward	Majority unknown	No wetlands
	Grindstone Wash-Upper Verde River	29	45%	None	Static to slightly downward	M/Static	No wetlands
	Oak Creek	69	33%	H/Static*	Slightly upward	L/Static	No wetlands
	Beaver Creek	78	50%	L/Away	Static to slightly downward	H/Towards	No wetlands
	Cherry Creek-Upper Verde River	3	45%	None	Static to slightly downward	L/Static	No wetlands
Lower Verde River	West Clear Creek	87	30%	None	Static to slightly downward	L/Towards	No wetlands
	East Verde River	100	No natives	None	Static to slightly downward	L/Away	No wetlands
	Fossil Creek-Lower Verde River	82	8%	L/Away (Fossil Creek)	Static to slightly downward	L/Static	No wetlands

* 5th code watersheds that contain perennial waters classified as Impaired by the Arizona Department of Environmental Quality

All watersheds are threatened by the potential for *catastrophic fire.* The watersheds are comprised of varying proportions of PNVTs that are outside their historic range of variability for fire regime condition class, i.e. Piñon Juniper Woodland and Ponderosa Pine. The high tree density and canopy cover of these PNVTs increase the susceptibility of these watersheds to *catastrophic fire* which could result in soil erosion, increased water flows, and sedimentation into the adjoining drainages and water courses. This could affect aquatic species as well as the stream landforms and processes. Grindstone Wash – Upper Verde River and Cherry Creek – Upper Verde River 5th codes, (Upper Verde 4th code) have the lowest risk. The remaining 5th codes have 75% or more of the watershed comprised of PNVTs with FRCC of 2 or 3. The following is a list of 4th code watersheds (and their associated 5th codes) and their aquatic characteristics at risk.

Middle Little Colorado River 4th code:

- Upper and Lower Clear Creek: Stream riparian condition, native fish habitat[51]
- Jacks Canyon: Water quality of lakes

Canyon Diablo 4th code:

- Rio de Flag, San Francisco Wash and Canyon Diablo: Wetland condition
- Walnut Creek: Water quality

Upper Verde River 4th code:

- Sycamore Creek and Grindstone Wash-Upper Verde River: Native fish habitat, stream riparian condition
- Oak Creek: Native fish habitat, water quality, stream riparian condition
- Beaver Creek: Native fish habitat, water quality
- Cherry Creek-Upper Verde River: Native fish habitat, stream riparian condition

Lower Verde River 4th code:

- West Clear Creek: Native fish habitat, stream riparian condition
- Fossil Creek-Lower Verde River: Native fish habitat, water quality, stream riparian condition

Every watershed on the Forest with the exception of the Lower Little Colorado River and Tonto Creek 4th codes has one or more aquatic characteristics at risk. The Upper and Lower Verde River 4th codes and Middle Little Colorado River 4th code have three characteristics at risk. Canyon Diablo 4th code has two characteristics at risk.

Table 44 shows prominent threats to aquatic ecosystem diversity characteristics by 4th and 5th code watershed and whether they are considered under agency management authority. Threats outside agency management authority are not considered further in the risk assessment.

[51] Even though the Middle Little Colorado River currently supports the same diversity of fish as it did historically, sustainability of native fish is threatened by nonnative aquatic species.

Table 44: Threats to aquatic ecosystem diversity by fourth and fifth code watersheds

	Middle Little Colorado River			Canyon Diablo				Upper Verde River					Lower Verde River	
Threat	**Upper Clear**	**Lower Clear Creek**	**Jacks Canyon**	**Rio de Flag**	**Walnut Creek**	**San Francisco Wash**	**Canyon Diablo**	**Cherry Creek – Upper Verde River**	**Grindstone Wash-Upper Verde River**	**Sycamore**	**Oak Creek**	**Beaver**	**Fossil-Lower Verde River**	**West Clear Creek**
Under agency management authority														
Fire exclusion in watershed	High risk							Lowest risk		High risk				
Uncharacteristic wildfire in watershed	High risk							Lowest risk		High risk				
Dispersed recreation use	X					.					X		X	
Highways, transportation corridors	X			X	X						X	X		
Cross country vehicle travel	X	Occurs but not major threat												
Outside agency management authority														
Drought	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Groundwater depletion				X	X			X			X	X	X	X
Nonnative invasive animals	X	X						X	X	X	X	X	X	X
Wildlife herbivory	X			X		X				X				
Contamination septic sewer											X			
Activities on non-NFS lands											X	X		

KEY FINDINGS

Many of these risks and threats are similar. Primary risks are: changing timing and duration of water flow, which affects water quantity and uses as well as water quality and designated uses (a key component for the determination of water quality). Conditions, threats and risks of vegetation, as described previously, influence aquatic resources. All of the watersheds have a high risk of uncharacteristic fire on the Forest, except for Grindstone Wash-Upper Verde River and Cherry Creek-Upper Verde River 5th codes in the Upper Verde River 4th code watershed. Sustainability of native fish in the streams in the watersheds that have non-native fish, bull frogs, crayfish or turtles are threatened because the nonnatives eat, compete with and can hybridize with native fish.

Perennial streams are fairly well represented because they are found in three out of seven 4th code watersheds on the Forest. The following is a list of aquatic characteristics at risk by 4th and 5th code watershed.

Middle Little Colorado River 4th code:

- Upper and Lower Clear Creek: Watershed and stream riparian condition
- Jacks Canyon: Watershed condition and water quality of lakes

Canyon Diablo 4th code:

- Rio de Flag, San Francisco Wash and Canyon Diablo: Watershed condition and wetland condition
- Walnut Creek: Watershed condition and water quality.

Upper Verde River 4th code:

- Water yield has a static to slightly downward trend due to groundwater pumping by nearby municipalities and communities.
- Sycamore Creek and Grindstone Wash-Upper Verde River: Native fish habitat, stream riparian condition
- Oak Creek: Watershed condition, native fish habitat, water quality, stream riparian condition,
- Beaver Creek: Watershed condition, native fish habitat, water quality
- Cherry Creek-Upper Verde River: native fish habitat, stream riparian condition.

Lower Verde River 4th code:

- Water yield has a static to slightly downward trend in this 4th code due to groundwater pumping by nearby municipalities and communities.
- West Clear Creek: Watershed condition, native fish habitat,
- East Verde River: Watershed condition, stream riparian condition
- Fossil Creek-Lower Verde River: Watershed condition, native fish habitat, water quality.

AIR

KEY FINDINGS

This risk assessment also includes analysis of potential threats to ecosystem diversity within airsheds. Threats the Forest Service has the ability to control or influence include smoke from fire suppression efforts and smoke from managed fire. As displayed in Table 34 earlier, these threats influence carbon monoxide, nitrogen dioxide and particulate matter levels. Threats outside of the Forest‘s ability to control or influence with management included smoke from uncontrolled wildfire, dust from landscape level wind events, and pollutants from urban areas and other land ownerships. Threats outside agency management authority will not be analyzed; however, Arizona Department of Environmental Quality monitors air quality to determine trends and compliance with state and federal standards.

Forest Service Handbook FSH 1909.12 discusses the two components of risk; the likelihood of a negative outcome, and the potential severity of a negative outcome. The above threats, singularly or in combination, pose similar risks. Poor air quality can affect human, animal and plant health, as well as recreational experience.

Risks to human, animal, and plant health from air quality issues on the forest are variable. Smoke generated from managed fire or suppression efforts is generally low to moderate in likelihood, as duration is generally low and extent is moderate. This is problematic in more populated areas, however, as severity can be high in adults and children with respiratory problems. Smoke duration and extent from managed fire is currently allocated statewide by ADEQ and involves all federal and state agencies, as well as tribes.

SPECIES RISK

The species list was reviewed for the purpose of assessing risks to species and their habitat. The list of species was divided into 2 groups:

- species associated with terrestrial and aquatic systems e.g. the prominent threats to the species are those associated with the habitat, and
- species that have threats in addition to and not fully addressed by threats to ecosystem and aquatic characteristics.

SPECIES ASSOCIATED WITH TERRESTRIAL AND AQUATIC SYSTEMS: Prominent threats to these species are addressed through the threats to the terrestrial and aquatic ecosystem characteristics described above. Aquatic ecosystem threats are those activities that physically modify hydrology, chemistry, geomorphology, perennial stream flow characteristics, plants and native fauna of aquatic systems including, but not limited to, recreation, construction or maintenance activities, and wildfire that causes excessive erosion in the watersheds, and herbivory which can also decrease plant numbers. These species and subspecies are listed in Table 45 and are not discussed further in this report. Although some species are associated with structural components of PNVTs such as snags, downed logs, specific tree sizes, openings, and

shrubs, these components are considered part of a PNVT functioning within the range of historic variability, and as such, are subject to the same threats as the PNVT.

Table 45: Species whose threats are addressed through threats to PNVTs or aquatic ecological characteristics

Taxon	*Scientific name*	Common name
Bird	*Buteo regalis*	Ferruginous hawk
Bird	*Buteogallus anthracinus*	Common black hawk
Bird	*Catharus ustulatus*	Swainson's thrush
Bird	*Coccothraustes vespertinus*	Evening grosbeak
Bird	*Ioporonis tolmiei*	MacGillivray's warbler
Bird	*Regulus satrapa*	Golden-crowned kinglet
Invertebrate	*Acrolophitus nevadensis*	Nevada pointed-headed grasshopper
Invertebrate	*Cicindela oregona maricopa*	Maricopa tiger beetle
Invertebrate	*Oeneis alberta daura*	Alberta Arctic
Invertebrate	*Aeshna persephone*	Persephone's darner
Invertebrate	*Piruna polingii*	Four-spotted Skipperling
Invertebrate	*Speyeria nokomis nitocris*	Nitocris Fritillary
Invertebrate	*Smicridea dispar*	A caddisfly
Invertebrate	*Wormaldia arizonensis*	A caddisfly
Mammal	*Lasiurus blossevillii*	Western red bat
Mammal	*Microtus mogollonensis navaho*	Navajo Mogollon Vole
Mammal	*Reithrodontomys montanus*	Plains harvest mouse
Mammal	*Sorex merriami leucogenys*	Merriam's Shrew
Plant	*Abies lasiocarpa var. arizonica*	Corkbark (subalpine) Fir
Plant	*Anulocaulis leiosolenus var. leiosolenus*	Southwestern ringstem
Plant	*Asclepias hallii*	Hall's Milkweed
Plant	*Asclepias quinquedentata*	Slimpod milkweed
Plant	*Botrychium crenulatum*	Crenulate Moonwort
Plant	*Botrychium echo*	Reflected Moonwort
Plant	*Botrychium lunaria*	Common moonwort
Plant	*Cystopteris utahensis*	Utah Bladder Fern
Plant	*Epilobium oregonense*	Oregon willowherb
Plant	*Isoetes bollanderi*	Bollander‘s quillwort
Plant	*Moneses uniflora*	Wood nymph
Plant	*Nuphar lutea*	Pond lily
Plant	*Penstemon caespitosus var. desertipicti*	Mat penstemon
Plant	*Phacelia crenulata var. augustifolia*	Cleftleaf scorpionweed
Plant	*Pinus aristata*	Bristlecone Pine
Plant	*Polemonium pulcherrimum ssp. delicatum*	Beautiful Jacob's Ladder
Plant	*Utricularia vulgaris*	Common bladderwort
Plant	*Xanthoparmelia huachucensis*	Huachuca Xanthoparmelia lichen

SPECIES WITH THREATS IN ADDITION TO THOSE FOR ECOSYSTEM DIVERSITY: The species list was reviewed to determine if there was a threat that precludes the

species from responding to changes in ecosystem diversity characteristics. Threats were identified that placed the species at risk for sustainability. If species are threatened by non-habitat threats, such as *disease, or collection*, then the threats were screened as to whether they are under the control and authority of the Forest Service. The focus was not on risks to individuals. If the threat was not under agency authority, the Forests contribution to sustainability of the species may be limited.

Threats associated with limited distribution and endemism: One hundred and seven species carried forward have *limited distributions* (found in few localities). Of these, 47 are *endemic* (occurs to a limited extent in the southwest). Some have very limited distribution or habitat in northern Arizona, or are only known from the Coconino NF. Endemic species and those with limited or restricted distributions are listed in Appendix J.

Risks to these species are associated with the narrowness of their range, the threats to the habitat at those locations and their rarity (number, size and distribution of populations). The Forest has a high contribution to the sustainability of these species because they are rare, are restricted to a narrow geographic area, or found only in certain locations on the Forest. These species have increased vulnerability to mortality, extinction, and disrupted life processes, that is, movements, reproduction, and gene flow. They are easily affected by localized or stochastic events.

Species whose prominent threats are those associated with ecosystem diversity and threats associated with endemism or limited distributions are listed in Table 46. They may possibly need additional Forest plan components to ensure sustainability.

Table 46: Species with threats associated with limited distribution or endemism in addition to threats to ecosystem or aquatic diversity

Taxa	*Scientific name*	Common name
Bird	*Rallus longirostris yumanensis*	Yuma clapper rail
Invertebrate	*Anacroneuria wipukupa*	A stonefly
Invertebrate	*Apatania arizona*	A caddisfly
Invertebrate	*Atopsyche sperryi*	A caddisfly
Invertebrate	*Atopsyche tripunctata*	A caddisfly
Invertebrate	*Baetodes arizonensis*	A mayfly
Invertebrate	*Chimarra primula*	A caddisfly
Invertebrate	*Culoptila kimminsi*	A caddisfly
Invertebrate	*Culoptila moselyi*	A caddisfly
Invertebrate	*Ithytrichia mexicana*	A caddisfly
Invertebrate	*Lepidostoma knulli*	A caddisfly
Invertebrate	*Nectopsyche dorsalis*	A caddisfly
Invertebrate	*Ochrotrichia ildria*	A caddisfly
Invertebrate	*Ophiogomphus arizonicus*	Arizona Snaketail
Invertebrate	*Polycentropus arizonensis*	A caddisfly
Invertebrate	*Polycentropus gertschi*	A caddisfly
Invertebrate	*Protoptila balmorhea*	Balmorhea saddle-case caddisfly
Invertebrate	*Pyrgulopsis morrisoni*	Page springsnail
Invertebrate	*Pyrgulopsis simplex*	Fossil Springsnail
Invertebrate	*Radiodiscus millecostatus*	Ribbed pinwheel
Mammal	*Perognathus amplus cineris*	Wupatki Arizona Pocket Mouse
Mammal	*Sorex nanus*	Dwarf shrew
Plant	*Aletes macdougalii*	Macdougal's Aletes
Plant	*Allium begelovii*	Bigelow‘s onion
Plant	*Astragalus rusbyi*	Rusby's Milk-vetch
Plant	*Astragalus subcinereus*	Silver Milkvetch
Plant	*Astragalus troglodytus*	Creeping Milk-vetch
Plant	*Isoetes bolanderi*	Bollander's quillwort
Plant	*Lepidium montanum var. glabrum*	Mountain Pepperweed
Plant	*Macromeria viridiflora var. thurberi*	Giant-trumpets
Plant	*Macromeria viridiflora var. viridiflora*	Giant-trumpets
Plant	*Mertensia macdougalii*	Macdougal's Bluebells
Plant	*Nuphar lutea*	Pond lily
Plant	*Penstemon caespitosus var. desertipicti*	Mat penstemon
Plant	*Phacelia crenulata var. angustifolia*	Cleftleaf scorpionweed
Plant	*Phacelia serrata*	Serrate Phacelia
Plant	*Phlox amabilis*	Arizona Phlox
Plant	*Potentilla crinita var. lemmonii*	Bearded Cinquefoil
Plant	*Sisyrinchium longipes*	Timberland Blue-eye-grass
Plant	*Sporobolus interruptus*	Black Dropseed

Species with threats not associated with ecosystem diversity characteristics

Species were grouped around key habitat elements finer or larger than landscape scale but not ecosystem diversity characteristics. These elements are called special features.

Special features include the following:

- Rocks: Rock features include canyons, cliffs, talus, and other rocky surfaces.
- Water features: Water features include hanging gardens, ephemeral pools, seasonally wet areas, wet ground, springs, seeps, and stock tanks.
- Human made structures: Bridges, buildings, archaeological sites, railroad beds.
- Soil type: Soils with different parent materials or mineral concentrations, such as limestone, sandstone, or basalt.

Species with threats in addition to those for ecosystem diversity or special features

Table 47 lists the special feature, the additional threats, and the species in the group. Species with *limited distributions* are shaded. *Endemic species* are in bold font. It is obvious by looking at the table that a variety of plant, bird, invertebrate and mammal species are primarily associated with the rock special feature. Plants are the primary taxa associated with archaeological sites, specific soil types, water features and the majority of these plants are endemic or have limited distributions. There are a number of aquatic invertebrates known only from specific locations, many of them from Oak Creek. Interestingly, Oak Creek has the largest number of species of caddisflies reported in any drainage in Arizona and includes more than 50% of species reported from Arizona (Blinn and Ruiter 2009).

Table 47: Species threats associated with special features

Habitat feature	Threats	Species name
Rocks (canyons, cliffs, ledges, caves, talus slopes)	Activities including rock climbing, caving, construction, mineral activities, and vandalism can alter or remove habitat. Caving modifies surface features, temperature and humidity levels in caves modifying the micro-environment for roosting or hibernating bats, possibly making the cave unsuitable or less suitable for occupancy. Habitat may be altered enough to prevent plant establishment, destroy plants, or affect the survival of talussnails.	• American peregrine falcon • Mexican spotted owl • **Walnut Canyon Talussnail** • **Oak Creek Talussnail** • **Milk Ranch Talussnail** • Pale Townsend's Big-Eared Bat • Allen's Lappet-Browed Bat • Arizona Myotis • **Arizona Bugbane** • Black spleenwort • Ebony spleenwort • Diamond Valley Suncup • **Mogollon Thistle** • **Rough Whitlow-grass (var. stelligera)** • **Cliff Fleabane** • Dane's dwarf gentian • Bearded gentian • **Senator Mine Alum-root** • Arizona Whitefeather • **Lyngholm's Cliffbrake** • **Compacted Rock Daisy** • **Alcove Bog-orchid** • **Thurber's Cinquefoil**
Human structures (buildings,bridges railroad beds)	Chemical and pesticide use and storage can poison species or prey. Maintenance, construction, and demolition activities and vandalism can damage or destroy features or individuals.	• Allen's Lappet-Browed Bat • Arizona Myotis • Macoun's false bindweed
Human structures (archaeological sites)	Ground or site disturbing activities and compaction around archaeological sites can decrease plant numbers, especially small regenerating plants.	• Tonto Basin Agave • Phillips' agave • **Verde Valley Sage**

Habitat feature	Threats	Species name
Soil type (Basalt, cinders)	Large scale ground disturbing activities including, but not limited to, recreation, road related work, construction and mineral withdrawal, can result in plant removal or damage.	• Porter's sandwort • Diamond Valley Suncup • Wild Buckwheat • **Jones' Wild Buckwheat** • Dane's dwarf gentian • Bearded gentian • **Basin Bladder-pod** • **Sunset Crater Beardtongue** • **Flagstaff Beardtongue** • Tufted saxifrage • Spider saxifrage
Soil type (Calcareous, alkaline, gypsum)	Invasive species can out-compete slower growing sensitive plants by taking up growing space, moisture, and nutrients and choking out native species.	• Southwestern ringstem • **Disturbed (Tusayan) rabbitbrush** • **Ripley's Wild-buckwheat** • Skunk-top Scurfpea • Toadflax Beardtongue • **Rusby's Milkwort** • **Verde Valley Sage**
Soil type (Dolomitic limestone and limestone)	Dolomitic limestone often forms bluffs from which recreationists view the landscape. Disturbance to soils in these areas due to dispersed camping or other management activities can destroy plants.	• **Mt. Dellenbaugh Sandwort** • **Disturbed (Tusayan) rabbitbrush** • Clustered leather-flower • **Jones' Wild Buckwheat** • **Ripley's Wild-buckwheat** • **Flagstaff Pennyroyal** • **Basin Bladder-pod** • **Mearns lotus** • Skunk-top Scurfpea • **Compacted Rock Daisy** • Western Flame-flower • **Rusby's Milkwort** • **Arizona Cliffrose** • **Verde Valley Sage** • Tonto Basin Agave

Habitat feature	Threats	Species name
Soil type (Sandstone)	Disturbance to sandstone soils due to dispersed camping or management activities can decrease plant numbers.	• Wild Buckwheat • **Jones' Wild Buckwheat** • **Lyngholm's Cliffbrake** • **Rusby's Milkwort** • **Verde Valley Sage** • Rothrock's Hedge-nettle
Soil type (Verde Formation)	Disturbance to Verde Formation soils, which has a unique chemical composition, can decrease plant numbers.	• **Heathleaf Wild Buckwheat** • **Ripley's Wild-buckwheat** • **Rusby's Milkwort** • **Arizona Cliffrose** • **Verde Valley Sage**
Water features (hanging gardens, seasonally wet areas, wet ground, springs, seeps),	Activities that physically modify hydrology, structure or composition of water features including, but not limited to, recreation, construction or maintenance activities, spring or seep related projects, and herbivory, which can decrease plant numbers; and can decrease larval host plants for butterflies.	• Nokomis Fritillary • **Arizona Bugbane** • Columbine • Cochise Sedge • **Mogollon Thistle** • **Jones' spider-flower** • **Rough Whitlow-grass (var. stelligera)** • **Arizona Sneezeweed** • Western Mouse-tail • Western Flame-flower • **Alcove Bog-orchid** • Western Porterella • **A Buttercup (var. subaffinis)** • **Oregon Buttercup** • **Blumer's Dock** • **Oak Creek Triteleia**

Some species have threats that are in addition to threats to ecosystem or aquatic diversity characteristics or to special features. These are listed in Table 48.

Table 48: Additional threats to species that are not associated with ecosystem diversity characteristics or special features

Additional primary threats not associated with habitat or feature	Species name
Human activities that result in *disturbance* can disrupt sensitive life stages such as breeding (birds and bats); and hibernation (bats). Activities include but are not limited to recreation, construction, vegetative treatments, and vandalism.	• Northern goshawks • Clark's grebe • Bald eagle (listed and non listed populations) • Mexican spotted owl • Southwestern willow flycatcher • American peregrine falcon • Allen's lappet-browed bat • Pale Townsend's big-eared bat • Arizona myotis • Southwestern myotis
Activities on lands in other ownership such as cattle grazing, stockyards, development, transportation corridors, railroads, fencing, dogs running loose	• Southwestern willow flycatcher • Gila monster • Pronghorn • Gunnison's prairie dog
Collection or *harvest* can result in loss of individuals to populations, or mortality.	• Northern goshawks • Bald eagle (listed and non listed populations) • Mexican spotted owl • Pronghorn • Mountain lion • Beaver • Gunnison's prairie dog • American peregrine falcon • Gila monster
Disease results in loss of individuals to populations or mortality of entire colonies as in Parvovirus (ferrets) and bubonic plague (prairie dogs), or loss of key prey (Western burrowing owls). *Human activities that result in the spread of disease or infected soil and water* from one occupied site to another can kill frogs and toads. Activities include recreation, fire and grazing management, research.	• Gunnison's prairie dog • Black-footed ferret • Western burrowing owl (loss of prairie dogs) • Arizona toad • Chiricahua leopard frog • Lowland leopard frog • Northern leopard frog
Illegal shooting results in loss of individuals to populations	• Mexican gray wolf
Nest parasitism from brown-headed cowbirds which associate with livestock reduces survival of the host species' young.	• Abert's Towhee • Southwestern willow flycatcher

Additional primary threats not associated with habitat or feature	Species name
Nonnative or invasive aquatic species eat, compete with, and hybridize with native aquatic species.	• **All native fish** • Sonora mud turtle • Chiricahua leopard frog • Lowland leopard frog • Northern leopard frog • Northern Mexican gartersnake • Narrow-headed gartesnake • California floater
Water impoundments provide habitat for Woodhouse's toads which hybridize with Arizona toads.	• Arizona toad
Development, dams, fencing, major transportation corridors, and *road construction and maintenance can* fragment habitat which can alter seasonal movements, dispersal, gene flow, and predator-prey relationships.	• Pronghorn • Mountain lion • Southwestern willow flycatcher • Beaver • **Native fish** • Narrow-headed gartersnake
Ungulate herbivory, managed and unmanaged grazing reduces the vigor, maintenance and survival of highly palatable plants. This can indirectly affect nesting habitat for Western yellow-billed cuckoos and Clark's grebe; and prey habitat for Mexican spotted owls and northern goshawks.	• Bebb's willow • Quaking aspen • Arizona cliffrose
Off trail hiking reduces the vigor, maintenance and survival of alpine tundra plants.	• Porter's sandwort • Crenulate moonwort • Common moonwort • Blackroot sedge • Different-nerve sedge • **San Francisco Peaks groundsel**
Lead poisoning causes behaviorial, physiological, and biochemical effects in individuals and can cause death.	• California condor

Table 49 describes threats to special features and to species and whether the threats are under agency control and authority. The Forest is limited in its ability to contribute to the sustainability of a species when the threats, or part of the threats, are outside the control or authority of the Forest Service. The primary threats under Forest Service management authority, at least in part, are human activities, chemical and pesticide use and storage, managed grazing, some impoundments, nonnative invasive plant and animal species, development, fencing, collection, and road and transportation corridors.

Table 49: Management authority of species or species habitat threats

Primary Threats under agency management authority
Human activities including rock climbing, caving, construction, maintenance, mineral activities, recreation, water related projects, vegetative treatments (including fire), off trail hiking, and vandalism. Forest Service has approval or enforcement authority for these activities on Forest land barring other jurisdictions, laws, regulations. Example of exceptions: locatable minerals, road work. Forest Service authority is subject to the limitations under the 1872 Mining Act. Some road work may be under other jurisdictions such as Federal Highways, or Arizona Department of Transportation.
Chemical and pesticide use and storage on Forest administered sites.
Human activities that result in the spread of disease (Bd) or infected soil and water from one occupied site to another. Forest has control and authority of access to areas inhabited by rare frogs on Forest lands.
Managed grazing Forest has management responsibilities for cattle grazing and the authority to construct grazing exclosures and adjust the timing of grazing.
Impoundments Some impoundments are permitted by the Forest Service, and others are not under Forest Service authority.
Nonnative invasive plant species: The Forest has the authority to treat these plant species subject to applicable laws and regulations.
Nonnative invasive animal species: The Forest has the authority to work with other agencies regarding non-native invasive animal species and can construct habitat related features such as barriers.
Development: Forest Service has authority to develop administrative sites, recreation facilities, and permit or allow energy or communication related infrastructure on Forest administered lands. Forest has no authority on lands in other ownership. Forest has authority to exchange lands in and out of Forest Service ownership which may or may not result in development.
Fencing: Forest has authority to build fences. Other entities have authorities to build and maintain fences within the Forest boundary including private land owners and state and federal agencies, such as with fences along road easements.
Collection: Permitted activities by the Forest Service usually include the removal of individual plants, plant parts, fungi, or the collection of invertebrates.
Roads and transportation corridors: Forest has authority to manage Forest roads. Cooperative relationships exist with entities that also have authority to manage roads within Forest boundaries such as counties, federal and state agencies, and private parties.

Primary threats outside agency management authority
Collection: U.S. Fish and Wildlife regulates the taking of Bald eagles, Southwestern willow flycatchers, Mexican spotted owls, and threatened and endangered fish. Some taking of animals occurs through falconry which is also regulated by Arizona Game and Fish Department. Species include: common black hawks and northern goshawks. Arizona Game and Fish Department also regulates nonnative fish, amphibian, and reptile populations.
Harvest: Arizona Game and Fish Department is responsible for harvest of wildlife populations. Species include: Gunnison's prairie dogs, mountain lions, pronghorn, and beaver.
Illegal shooting: Shooting that involves illegal species, weaponry, season, location, etc. Law enforcement is the responsible entity and jurisdiction varies depending on the individual violation.
Excessive wildlife herbivory. Arizona Game and Fish Department is responsible for management of wildlife populations. Forest Service can erect fence exclosures and coordinate with the State on habitat issues and opportunities.
Diseases such as bubonic plague or canine distemper.
The primary source of *lead poisoning* in California condors is ammunition which is not regulated by the Forest Service.
Cattle grazing or livestock concentrations (such as stockyards) on lands other than Forest Service
Activities on lands in other ownership are not under the authority of the Forest Service.

CHAPTER 5: ECOLOGICAL NEED FOR CHANGE

SUMMARY OF MAJOR FINDINGS - ECOSYSTEM DIVERSITY

TERRESTRIAL SYSTEMS

The ecological need for change highlights which management activities *under Forest Service control and authority* can influence the landscape-level departures in composition, structure and processes, improve resiliency, and contribute towards species diversity across the landscape.

The ecological need for change section of this report uses the information presented in previous chapters. It focuses on:

- existing landscape departures from historical conditions,
- PNVTs or watersheds are at risk of loss of sustainability at multiple scales,
- T&E species, Forest planning species, and,
- Forest contributions to the sustainability of the ecosystems.

An overarching need for change in the majority of the PNVTs is to move vegetation structure, fire frequency, and fire severity towards reference conditions; restore soil condition and productivity; and control the spread and establishment of nonnative, invasive weeds. The sustainability of habitat for species is also at risk.

Structure and composition of vegetation are at risk because of the *exclusion of fire, managed grazing*, *nonnative invasive plant species*, and *increased threat of catastrophic fire.* Improvements in vegetation condition are ecological needs for change in the following PNVTs:

- Desert Community PNVT – Reduce canopy cover and competition with native plant species from invasive annual grasses.
- Semidesert and Montane Subalpine Grassland PNVTs - Decrease shrubs, trees, and canopy cover to increase diversity and abundance of native understory.
- Piñon Juniper Woodland and Piñon Juniper Evergreen Shrub PNVTs - Reduce canopy cover and tree density to increase understory. Shift age class diversity to larger trees.
- Ponderosa Pine and Dry Mixed Conifer PNVTs – Reduce canopy cover and high density of medium sized trees to an all-aged primarily open forest. Increase understory and early succession tree species. Increase native understory diversity by reducing nonnative invasive plants.
- Cottonwood Willow Riparian, Mixed Broadleaf Deciduous Riparian, and Montane Willow Riparian PNVTs – Increase understory. Shift age class diversity and canopy cover closer to reference conditions.

Historic fire regime condition classes are at risk because of the *exclusion of fire* which can lead to *uncharacteristic fire*. Restoration and maintenance of historic fire regime condition classes are needs for change in the following PNVTs:

- Piñon Juniper Woodland, Ponderosa Pine, Dry Mixed Conifer PNVTs – the risk of losing key ecosystem components from severe fires is high. *Key ecosystem components* include vegetative attributes such as species composition, structural stage, stand age, canopy cover and fuel loading.
- Semidesert Grassland, Interior Chaparral – the risk of losing key ecosystem components from severe fires is moderate.
- Great Basin Grassland, Montane Subalpine Grassland, Montane Willow Riparian Forest – the risk of tree invasion is moderate because of fire exclusion in adjacent fire adapted PNVTs.

Soil condition and soil productivity are at risk due to off highway vehicle use, improperly located roads, or exclusion of fire. These characteristics have also been impacted by historical grazing and are responding slowly to improved grazing strategies however improvements in soil condition or productivity are needs for change in the following PNVTs:

- Desert Communities, Semidesert Grassland, Great Basin Grassland, Piñon Juniper Woodland, Piñon Juniper Evergreen Shrub, Wetland Cienega, and the montane portion of Montane Subalpine Grassland.

Native plant diversity and historic fire return intervals are at risk due to *nonnative invasive plants, including grasses.* Limiting the spread and establishment of these plants is a need for change in the following PNVTs:

- Desert Communities and Semidesert Grassland PNVTs – especially invasive grasses which can alter fire regime condition class.
- Great Basin Grassland, Ponderosa Pine, Dry Mixed Conifer, Mixed Broadleaf Deciduous Riparian Forest, Piñon Juniper Evergreen Shrub, Piñon Juniper Woodland, and Montane Subalpine Grassland PNVTs.
- Cottonwood Willow Riparian Forest – invasive grasses can alter fire regime condition class and invasive riparian plants can alter ecosystem hydrology.

Subsections: The Coconino has high contribution at the section level to the sustainability of the PNVTs that are shaded in Tables 50 and 51. Moderate contributions are unshaded. Departures at the subsection scale are shown in these tables and help identify and narrow where vegetative departures of the PNVT are more or less severe. Great Basin Grassland and Piñon Juniper Woodland PNVTs are more highly departed in subsections 313Db and 313De which occur in the extreme north and northeast part of the Forest. Montane Subalpine Grassland is more highly departed in subsection M313Af in the southern part of the Forest. The remaining PNVTs have more consistent departures in their respective subsections. Subsection departures may help prioritize where management actions should be considered.

Table 50: Percent Forest departure by subsection for PNVTs that cover > 1% of the Forest

		% Forest departure in subsection		
Major PNVT	**Subsection**	**High 66%-100%**	**Moderate 65%-33%**	**Low 32%-0%**
Semi-Desert Grassland	313Ca, 313Cc, 313Cd, M313Al	X		
Great Basin Grasslands	313Db	X		
	313De		X	
	M313Ak, M313Al			X
Interior Chaparral	313Cd, M313Al			X
Piñon Juniper Evergreen Shrub	313Ca, 313Cc, 313Cd, M313Af, M313Ak, M313Al		X	
Piñon Juniper Woodland	313Dd, 313De	X		
	M313Ak, M313Al		X	
Ponderosa Pine	313Cd, 313Dd, 313De, M313Af, M313Ak, M313Al	X		
Dry Mixed Conifer	313Cd	Too few subsection acres to analyze		
	M313Af, M313Ak, M313Al	X		
Montane/Subalpine Grassland	313Cd, M313Ak, M313Al			X
	M313Af	X		

Table 51: Percent Forest departure by subsection for PNVTs that make up < 1% of the Forest

PNVTS <1% of Forest	Subsection	High 66%-100%	Moderate 65%-33%	Low 32%-0%
Cottonwood Willow	313Ca, 313Cc, 313Cd		X	
Mixed Broadleaf Deciduous	313Ca, 313Cc, 313Cd, M313Al		X	
	M313Af	X		
Wetland Cienega	M313Af, M313Al, M313Ak		X	
Montane Willow	M313Af, M313Al		X	
	313Ca, 313Cc, 313Cd	Too few subsection acres to analyze		
Desert Communities	313Ca, 313Cc, 313Cd	X		
Spruce Fir	M313Al		X	
Alpine Tundra	M313Al			Considered low

The following table groups PNVTs by the level of Forest contribution and provides summary information about their departures, number of associated species and related ecological needs for change, based on activities under the control and authority of the Forest Service.

Table 52: PNVT departures, number of associated species, and ecological needs for change where the Forest has a high contribution to sustainability

PNVT (Districts[52] where primarily found)	Forest vegetation departure and trend	Fire Regime Condition Class departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	# Associated species	Ecological need for change
High Forest contribution to sustainability					
Desert Communities (2)	H - Unknown	Not a major ecological process	H - Static (99%)	1 T&E, 12 Forest planning species	➢ Improve vegetation structure and composition conditions by increasing canopy closure of older shrubs and by maintaining % cover of native species. Limit establishment and spread of annual grasses. ➢ Improve soil condition, (water infiltration and nutrient recycling) and soil productivity, including surface litter, by decreasing the rates of erosion and soil compaction.
Semi-Desert Grasslands (2)	H - Away	M - Away	H - Static (72%)	16 Forest planning species	Restore appropriate fire regime condition class. ➢ Improve vegetation structure by decreasing tree density and overstory canopy closure. ➢ Improve vegetation composition by increasing % cover of native plants and limiting the spread and establishment of nonnative, invasive plants, including annual grasses. ➢ Improve soil condition, water infiltration and nutrient cycling by decreasing rates of erosion and soil compaction. ➢ Improve soil productivity by increasing amount of litter and organic matter.
Piñon Juniper Evergreen Shrub (2)	M - Away	M - Away	M – Static (61-66%)	21 Forest planning species	➢ Improve vegetation structure by creating more open stand structure and by decreasing tree density. ➢ Improve vegetation composition by increasing the percent cover of native plants and limiting the spread and establishment of nonnative, invasive plants such as Lehmann's lovegrass. ➢ Restore appropriate fire regime condition class. ➢ Improve soil productivity, soil condition and nutrient cycling by decreasing percentage of soil erosion through creating more open stand structure, and increasing litter and plant cover.

[52] 1 = Peaks/Mormon Lake, 2 = Red Rock, 3 = Mogollon Rim

PNVT (Districts[53] where primarily found)	Forest vegetation departure and trend	Fire Regime Condition Class departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	# Associated species	Ecological need for change
Great Basin Grassland (1,3)	L - Unknown	H - Away	H - Towards (87%)	1 T&E and 7 Forest planning species	➢ Restore appropriate fire regime condition class. ➢ Improve vegetation structure by increasing understory vigor and production and decreasing tree density especially in the northeast part of the Forest. ➢ Improve vegetation composition by increasing percent cover of native plants and limiting the spread and establishment of nonnative, invasive plants. ➢ Improve soil productivity, nutrient cycling, hydrologic function and condition by increasing soil organic matter through reducing tree densities in some areas.
Ponderosa Pine (1,3)	H - Away	H - Away	L - Static (1-2%)	1 T&Eand 53 Forest planning species	➢ Improve vegetative structure and composition by creating more open stand structure, decreasing tree density, and increasing the proportion of open, all-aged forest. ➢ Improve vegetation structure and composition (including for early successional species such as aspen) by restoring appropriate fire regime condition class. ➢ Improve overstory and understory composition by increasing the percent cover of native species; limiting the spread and establishment of nonnative, invasive plants, such as camelthorn and diffuse knapweed, and eradicating invasive plants where feasible. ➢ Improve nutrient cycling function by creating more open stand structure.

[53] 1 = Peaks/Mormon Lake, 2 = Red Rock, 3 = Mogollon Rim

PNVT (Districts[54] where primarily found)	Forest vegetation departure and trend	Fire Regime Condition Class departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	# Associated species	Ecological need for change
Dry Mixed Conifer (1,3)	H - Static	H - Away	L - Static (0%)	1 T&E and 21 Forest planning species	➢ Improve vegetative structure by creating more open stand structure, decreasing the density of trees, and increasing proportion of open, all-aged forest. ➢ Improve vegetation structure and composition (including for early successional species such as aspen) by restoring appropriate fire regime condition class. ➢ Improve vegetative composition by increasing the percentage of native species and limiting the spread and establishment nonnative, invasive plants, such as camelthorn and diffuse knapweed.
Spruce Fir (1)	M - Towards	M - Unknown	L - Static (0%)	17 Forest planning species	➢ Improve vegetative structure and composition by restoring the appropriate fire regime condition class.
Alpine Tundra (1)	L - Away	Not a major ecological process	L - Static (0%)	1 T&E and 13 Forest planning species	No identified needs for change.

[54] 1 = Peaks/Mormon Lake, 2 = Red Rock, 3 = Mogollon Rim

Table 53: PNVT departures, number of associated species, and needs for change where the Forest has a moderate contribution to sustainability

PNVT (Districts[55] where primarily found)	Forest vegetation departure and trend	FRCC departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	# associated species	Need for change
Moderate Forest contribution to sustainability					
Interior Chaparral (2)	L - Static	M - Away	L - Static (<1%)	3 Forest planning species	➢ Maintain vegetative structure and composition by restoring appropriate fire regime condition class.
Cottonwood Willow Riparian (2)	M - Unknown	Not a major ecological process	H – Static (97-98%)	3 T&E and 12 Forest plannin species	➢ Improve vegetation structure and composition conditions by increasing herbaceous and woody understory as well as seedling and saplings. ➢ Improve soil condition and soil productivity by increasing surface litter, understory production, and protective ground cover. ➢ Improve vegetative composition, structure and function by limiting the spread and establishment nonnative, invasive plants and increasing the percentage of native plant cover.
Mixed Broadleaf Deciduous Riparian (1,2,3)	M - Unknown	Not a major ecological process	L - Static (1-2%)	1 T&E and 19 Forest planning species	➢ Improve vegetative composition by limiting the spread and establishment nonnative, invasive plants, such as red brome, ripgut brome, and Himalayan blackberry. ➢ Maintain soil condition and productivity.
Wetland Cienega (1,3)	L - Unknown	Not a major ecological process	H - Static (99%)	8 Forest planning species	➢ Improve soil condition, water infiltration, nutrient cycling, and soil productivity by increasing water infiltration, litter and vegetative cover.
Montane	M -	H -	L - Static (~3%)	9 Forest	➢ Improve vegetation structure and composition conditions by increasing

[55] 1 = Peaks/Mormon Lake, 2 = Red Rock, 3 = Mogollon Rim

PNVT (Districts[55] where primarily found)	Forest vegetation departure and trend	FRCC departure and trend	Soil condition/ productivity departure and trend (% unsatisfactory + impaired)	# associated species	Need for change
Willow Riparian (1,3)	Unknown	Unknown		planning species	percentage cover of riparian species and decreasing percentage cover of conifer species. ➢ Restore fire frequency or equivalent disturbance. ➢ Maintain soil condition and productivity.
Piñon Juniper Woodland (1,3)	M - Static	H - Away	M - Static (30%)	24 Forest planning species	➢ Improve vegetation (structure and composition attributes) conditions. ➢ Restore appropriate fire regime condition class. ➢ Improve nutrient cycling and decrease erosion by decreasing tree density where canopy cover exceeds 40% and by increasing vegetative productivity. ➢ Improve soil productivity by increasing surface litter and vegetative productivity. ➢ Limit the spread and establishment nonnative, invasive plants, such as camelthorn and diffuse knapweed.
Montane Subalpine Grassland (1,3)	M - Unknown	H - Away	H - static[56] (67-72%)	1 T&E and 15 Forest planning species	➢ Improve vegetation (structure and composition attributes) conditions. ➢ Restore appropriate fire regime condition class. ➢ Improve soil condition by increasing percentage of native vegetative ground cover and improving ability of soil to infiltrate water in montane meadows. ➢ Improve soil productivity by increasing the percentage cover of litter and herbaceous productivity in montane meadows. ➢ Improve vegetative composition by increasing the percent cover of native plants and by limiting the spread and establishment nonnative, invasive plants, such as leafy spurge.

[56] Montane portion only

Aquatic Systems

The 4th code watershed of highest concern is the Middle Little Colorado River because the Forest has higher than expected contribution to the sustainability of perennial streams. Other 4th code watersheds with aquatic characteristics at risk are: Upper Verde River, Lower Little Colorado River, Canyon Diablo and Lower Verde River. Table 54 provides summary information about 4th and 5th code watershed departures, number of associated species, and related ecological needs for change. Wetland riparian condition is displayed as the percentage of the wetland acreage classified as Functional-At-Risk (FAR). These acres are defined as wetland areas that are in functional condition but an existing soil, water, or vegetation attribute makes them susceptible to degradation. Only activities under the control and authority of the Forest Service are discussed below.

Table 54: At-risk aquatic characteristics by fourth and fifth code watersheds and needs for change

4th Code Watersheds	5th Code Watersheds (Districts[57] where located)	Water Quality	Stream Riparian Condition Departure and Trend	Dominant Wetland Riparian Condition % Departure and Trend	% Departure Current # Native Fish Compared to Reference	# At-risk aquatic species	Ecological Need for Change
Middle Little Colorado River	Upper Clear Creek[58] (3)	Not impaired	H - Static	24% FAR (114 acres) static	0%	8	➢ Improve stream riparian condition by increasing the number of stream miles in proper functioning condition. ➢ Improve aquatic habitat for native fish by reducing or removing nonnative invasive aquatic species. ➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.
	Jacks Canyon (3)	H – Static (lakes)	Not applicable	PFC (6 acres) static	Not applicable	None	➢ Reduce mercury levels in fish in Long Lake, Soldier, and Soldier Annex lakes by decreasing erosion and sedimentation in lakes for example from wildfire and roads.
Canyon Diablo	Rio de Flag (1)	Not applicable	Not applicable	100% FAR (15 acres) - static	Not applicable	1	➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.
	Walnut Creek (1)	H - Away (lakes)	Not applicable	PFC (24 acres) static	Not applicable	1	➢ Reduce mercury levels in fish in Upper Lake Mary and Lower Lake Mary by decreasing erosion and sedimentation in lakes for example from wildfire and roads.
	San Francisco Wash (1)	Not applicable	Not applicable	54% FAR (490 acres) static	Not applicable	1	➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.
	Canyon Diablo 5th code	Not applicable	Estimated L-static	16% FAR (96 acres) static	Not applicable	1	➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.
Lower Little Colorado River	Upper Cedar Wash (1)	Not applicable	Not applicable	14% FAR (4 acres) static	Not applicable	None	➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.

[57] 1 = Peaks/Mormon Lake, 2 = Red Rock, 3 = Mogollon Rim

[58] Lower Clear Creek is assumed to have same current and historic distribution of fish as Upper Clear Creek however inventory is lacking.

4th Code Watersheds	5th Code Watersheds (Districts[57] where located)	Water Quality	Stream Riparian Condition Departure and Trend	Dominant Wetland Riparian Condition % Departure and Trend	% Departure Current # Native Fish Compared to Reference	# At-risk aquatic species	Ecological Need for Change
Upper Verde River	Sycamore Creek (1,2)	Not applicable	Mostly unknown	98% FAR (100 acres) static	50%	6	➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition. ➢ Improve aquatic habitat for native fish (4 T&E fish occurred historically) by reducing or removing nonnative invasive species.
	Grindstone Wash-Upper Verde River (2)	Not applicable	L – Static	No wetlands	45%	6	➢ Improve aquatic habitat for native fish (5 T&E fish occurred historically) by reducing or removing nonnative invasive species.
	Oak Creek (1,2)	H - Static (Oak and Spring Crk)	L - Static	No wetlands	33%	32	➢ Improve water quality in Oak and Spring Creeks by reducing E. coli bacteria especially during busy weekends. ➢ Reduce turbidity (total suspended sediment) in Oak Creek by reducing sediments coming from roads and hillsides and increasing vegetative productivity. ➢ Improve aquatic habitat for native fish (5 T&E fish occurred historically) by reducing or removing nonnative invasive species.
Upper Verde River	Beaver Creek (1,2,3)	L – Away (Beaver Crk) H - Static (Stoneman Lake)	H - Towards	PFC - static	50%	9	➢ Improve water quality in Stoneman Lake by decreasing nutrient input. ➢ Improve stream riparian condition by increasing the number of stream miles in proper functioning condition. ➢ Improve aquatic habitat for native fish (5 T&E fish occurred historically) by reducing or removing nonnative invasive species.
	Cherry Creek-Upper Verde River (2)	H - Towards	L - Static	No wetlands	45%	8	➢ Improve water quality (total suspended sediment) in the Verde River by reducing incoming sediments and improving vegetative productivity. ➢ Improve aquatic habitat for native fish (5 T&E and 3 forest planning species occurred

4th Code Watersheds	5th Code Watersheds (Districts[57] where located)	Water Quality	Stream Riparian Condition Departure and Trend	Dominant Wetland Riparian Condition % Departure and Trend	% Departure Current # Native Fish Compared to Reference	# At-risk aquatic species	Ecological Need for Change
							historically) by reducing or removing nonnative invasive species.
Lower Verde River	West Clear Creek (2,3)	Not impaired	L – Towards	PFC - static	30%	10	➢ Improve aquatic habitat for native fish (5 T&E fish occurred historically) by reducing or removing nonnative invasive species.
	Fossil Creek-Lower Verde River (2,3)	H - Towards (Verde River) L - Away (Fossil Creek)	L - Away	12% FAR (3 acres) static	8%	14	➢ Improve water quality (total suspended sediment) in the Verde River by reducing incoming sediments and improving vegetative productivity. ➢ Improve water quality in Fossil Creek by reducing incoming sediments and E.coli bacteria. ➢ Improve stream riparian condition by increasing the number of stream miles in proper functioning condition. ➢ Improve aquatic habitat for native fish by reducing or removing nonnative invasive species. ➢ Improve wetland riparian condition by reducing compaction and increasing vegetative productivity and composition.

Stream riparian condition is at risk because of impacts from *non-point sources of sediments*. These sources include *improperly located roads, road construction and maintenance, dispersed recreation, managed grazing,* and *vegetative treatments*. Improve stream riparian condition by increasing the number of stream miles in proper functioning condition. Improvement of stream riparian condition is a need for change in the following watersheds:

- Middle Little Colorado River 4th code - Upper Clear Creek 5th code
- Upper Verde 4th code – Beaver Creek 5th code
- Lower Verde 4th code – Fossil Creek-Lower Verde 5th code

State water quality standards have been exceeded because of *elevated mercury in fish* from a *yet-to-be-determined source*, because of the *presence of Escheria coli bacteria* from the *improper sanitary habits of swimmers during busy weekends,* and because of *high levels of turbidity* due to roads and dispersed recreation. Reduce mercury levels in fish by adhering to the Arizona Department of Environmental Quality's TMDL plan when it is finalized. Improve water quality by reducing E. coli bacteria during busy weekends. Water quality improvement is needed in the following watersheds:

- Middle Little Colorado River 4th code – Long, Soldier, and Soldier Annex reservoir lakes – elevated mercury
- Canyon Diablo 4th code – Upper Lake Mary and Lower Lake Mary reservoir lakes – elevated mercury
- Upper Verde 4th code – Oak Creek 5th code – *E. coli* bacteria and turbidity; Beaver Creek 5th code – increased nutrients, Cherry Creek-Upper Verde 5th code – turbidity
- Lower Verde 4th code - Fossil Creek-Lower Verde 5th code – elevated *E.coli* bacteria and increased turbidity may cause future exceedences of State water quality standards.

Wetland riparian condition is at risk because of *legacy effects from stock tanks and historic grazing.* There is a need to improve wetland riparian condition in all 4th code watersheds but particularly in the following due to larger extent of wetlands classified as Functional-At-Risk:

- Middle Little Colorado 4th code – Upper Clear Creek 5th code
- Canyon Diablo 4th code – San Francisco Wash and Canyon Diablo 5th codes
- Upper Verde River 4th code – Sycamore Creek 5th code

Aquatic species habitat is at risk because of *the presence of non-native fish or aquatic species.* There is a need to reduce or eliminate non-native fish or aquatic species to improve the distribution, reproductive success, and long term sustainability of native aquatic species in the following watersheds:

- Middle Little Colorado, Upper Verde River and Lower Verde River 4th codes. Though the current number of native fish in the Middle Little Colorado 4th code is the same as historic (0% departure), this watershed contains a high number of non-native fish species that threaten the resiliency and long term sustainability of native fish habitat.

<u>Airsheds</u>

Forest emissions interact with air pollution from non-FS sources and topography to increase air quality concerns in the Verde River and Little Colorado River Airsheds, and Sycamore Canyon Class I area. Factors under control and authority of the Forest Service that contribute to risk include *prescribed burning* and *wildfires*. Given that the Coconino coordinates with other agencies such as ADEQ and EPA to maintain air quality standards and will continue to do so, there is currently no identified need for change.

Species Diversity

All the species that have been analyzed are at some level of risk. This risk stems from threats associated with departures in terrestrial or aquatic habitat, or species specific threats. These threats warrant further consideration in the plan revision process.

Next Steps in the Forest Plan Revision Process

The key findings from this ecological sustainability report and the social-economic sustainability report will be integrated to create a Comprehensive Evaluation Report (CER). The Comprehensive Evaluation Report will focus on which needs for change identified in the two sustainability reports can be addressed through the Forest Plan direction.

The Comprehensive Evaluation Report, along with other information, including public, tribal and other agency comments, will be reviewed by the Coconino National Forest leadership team to identify the initial scope of what will be addressed in the Forest Plan revision process.

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APPENDIX A: GLOSSARY

Avalanches: Avalanches are a natural process at high elevations. There can be excessive site specific erosion from avalanches which result in damage to vegetation. There can also be site specific removal of soil and vegetation in Alpine Tundra from blasts to reduce avalanche hazard to people.

Best Management Practices: With respect to water resources, a practice or a combination of practices, that is determined by a State (or designated area-wide planning agency) after problem assessment, examination of alternative practices and appropriate public participation to be the most effective, practical (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

Dams and impoundments: There are two dams and impoundments not subject to Forest control and authority: CC Craigen and Upper Lake Mary.

Developed recreation: This includes campgrounds, picnic areas, trailheads, information sites, swimming sites, boat ramps, and ski areas. These areas can have site specific impacts to composition, structure and processes resulting from high or long term use but do not have landscape level PNVT impacts. Impacts can include soil loss and compaction, vegetation loss and damage, and increased likelihood for the establishment or spread of nonnative invasive plants. There is also increased likelihood for the introduction of nonnative invasive animals. Arizona Game and Fish Department is the responsible entity for the management of these organisms.

Drought and flooding: These are natural processes on the landscape. Drought is a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area. Flooding is essential for the sustainability of riparian areas. The Forest can‘t control the onset, location or duration of these processes, however, can influence the resiliency of ecosystems.

Fire: Fire has historically been a natural process that modifies structure and composition of overstory and understory. Fire alters tree density and canopy cover, influences the distribution of tree age classes, and growth and establishment of young trees. It creates conditions that establish early successional species such as aspen; influences nutrient cycling; and can also sterilize soil, increase erosion and kill vegetation.

Prescribed fires and wildland fire use (fires managed for resource benefit) (planned and unplanned ignitions) can mimic some of the effects of this natural process. Wildfires, however, may exceed the effects of a natural fire in severity and size. Fire suppression can mitigate or stop the unwanted effects of wildfire and at same time promote unnatural effects to composition, structure of ecosystems and can interrupt natural processes. These different aspects of fire (managed fire, wildfire, lack of fire, and fire suppression) were considered threats and under the authority of the Forest.

Ecological niche: The degree to which the Forest provides for ecosystem and species diversity relative to the surrounding area is the _ecological niche'. The ecological niche is described by examining the various ecological communities that are represented within and outside the boundaries of the Forest and by analyzing the distribution of these communities and departures from reference conditions.

Ecoregions: Commonly referred to as Bailey's Ecoregions (Bailey 1996), provides a standardized method for classifying, mapping, and describing ecological units at various geographic planning and analysis scales. Ecoregions are ecosystems of regional extent. Bailey's ecoregions distinguish areas that share common climatic and vegetation characteristics. A four-level hierarchy is used to differentiate the ecoregions, with the broadest classification being the domain. Domains are groups of related climates and are differentiated based on precipitation and temperature. There are four domains used for worldwide ecoregion classification and all four appear in the United States: the polar domain, the humid temperate domain, the dry domain, and the humid tropical domain. Divisions represent the climates within domains and are differentiated based on precipitation levels and patterns as well as temperature. Divisions are subdivided into provinces, which are differentiated based on vegetation or other natural land covers. Mountainous areas which exhibit different ecological zones based on elevation are identified at the province level. Sections are subdivisions of provinces based on terrain features. Subsections are subdivisions of sections based on vegetation.

Ecosystem diversity*:* The variety and relative extent of ecosystem types, including their composition, structure, and processes within all or a part of an area of analysis.

Endemic species: Species whose occurrence is limited to a specific geographical area.

Firewood: Firewood gathering is managed by the Forest and the Forest has the legal authority to control illegal firewood gathering although is limited in ability to be effective in all areas due to budget and personnel. Specific areas open to fuelwooding are identified on a map issued annually with a permit.

Grazing, as used in this report, is defined in the Livestock Grazing Report (USDA Forest Service 2007). There are two basic types of grazing defined: managed herbivory and unmanaged herbivory.

- *Managed Herbivory:* Herbivory conducted in such a manner as to provide for progress toward the achievement of resource management objectives, which are the means of measuring progress toward achieving or maintaining desired conditions. The grazing tools of timing, intensity, frequency, grazing occurrence, and grazing period are managed to provide for the progress towards resource management objectives and desired conditions. On the Coconino NF, this is the permitted livestock program.

  Unmanaged Herbivory: Herbivory is conducted in such a manner that progress toward the achievement of resource management objectives cannot be assured. The grazing tools of timing, intensity, frequency, grazing occurrence, and grazing period are not controlled. Therefore, the foundation for adaptive management does not occur with unmanaged herbivory. Monitoring is critical to determine if unmanaged herbivory is

contributing to resource conditions which are not moving toward or maintaining desired conditions. Unmanaged grazing could be livestock if they are not managed to meet desired conditions or wildlife if grazing occurs at levels that prevent the attainment of desired conditions.

Grazing can modify the structure and composition of herbaceous and woody understory and influence ecosystem processes such as properly functioning soil and riparian areas, and fire regime. Numbers of wildlife are the responsibility of Arizona Game and Fish Department. The timing, location and extent of wildlife use are not controlled by the Forest; however, the Forest has limited ability to mitigate excessive use by building fences.

Herpetofauna: Amphibians and reptiles

Hydric soils: Soils formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrologic Unit Code (HUC): Hydrologic unit codes are a way of identifying all of the drainage basins in the United States in a nested arrangement from largest to smallest. A drainage basin is an area or region of land that catches precipitation that falls within that area, and funnels it to a particular creek, stream, and river and so on, until the water drains into an ocean. The term watershed is often used in place of drainage basin. This report refers to both 4th code (larger) and 5th code (smaller) HUCs.

Insects, disease, pathogens and parasites: Insect, disease, pathogens and parasites were considered threats and under the authority of the Forest to a limited extent. They are part of the natural disturbance regime. The Forest doesn‘t control insects or other organisms but can influence vegetative conditions to a limited extent so that areas are more resilient to outbreaks.

Invasive species: To a limited extent, the Forest can control the spread and establishment of invasive plants and animals. For animals, this category includes invasive and nonnative species such as crayfish, other nonnative invertebrates, and nonnative fish and reptiles. It does not include introduced or reintroduced animals such as elk or grouse which are considered socially desirable. The Forest is constrained because: spread of invasive plants and animals can occur via factors the Forest does not control (animals, wind, and water); control of populations may be under the jurisdiction of other agencies; and successful establishment is influenced by many factors including native species lacking defense mechanisms for nonnative organisms. Invasive species influence and can significantly disrupt the composition and structure of ecosystems as well as natural processes.

Mid-scale vegetation: Mid-scale vegetation types were determined using satellite data and were mapped at the scale of 1:100,000. Mid-scale inventory was conducted in 2005 and 2006.

Minerals: Minerals refer to the exploration and extraction of locatable, leasable, and salable/common variety minerals (see Minerals Report – USDA Forest Service 2009e).

- *Locatable minerals:* Locatable minerals include gold, silver, uranium and many others. Locatable mineral uses can occur unless the lands are withdrawn from mineral entry under the 1872 Mining Law.

- *Leasable minerals:* Leasable minerals are not locatable and are subject to leasing under the Mineral Leasing Act and include oil, gas, gypsum, and geothermal. By the lease terms, the lessee has the legal right to drill or mine subject only to the terms and conditions of the lease.
- *Salable/common variety minerals:* These minerals are not locatable and are subject to sale under the Material Sale Act. Salable materials include items such as cinders, pumice, sand, gravel, and decorative or building stone. All National Forest land is available for the removal of mineral materials where the resource occurs, unless it is specifically prohibited by law or formal administrative withdrawal.

Noxious Weed: Noxious weed is a legal term applied to plants regulated by Federal and State Laws, such as plants designated as noxious weeds by the Secretary of Agriculture or by the responsible State official. Noxious weeds generally possess one of the more of the following characteristics: aggressive and difficult to manage, poisonous, toxic, parasitic, a carrier or host of serious insect or disease, and being not native or new or not common to the United States or parts thereof. (Forest Service Manual 2080.5, Federal Noxious Weed Act of 1974, PL 93-629, as amended.)

Pesticide use on Forest Service land: Pesticides include herbicides, piscicides and pesticides. Regulation of the use of pesticides is under the control of the Environmental Protection Agency but authorization of the use on Forest Service lands is under Forest Service authority. The Forest follows strict guidelines for application. In all PNVTs, pesticide effects may last 10-15 years due to repeated applications including: mortality to target plants, mortality to non-target plants, and opening up vegetation where target plants formerly existed with potentially short term accelerated erosion.

Potential Natural Vegetation Type (PNVT): biophysically based ecological units that depict the potential vegetation type that would dominate a site under historic fire regimes and biological processes (Vander Lee and Smith 2006)

PFC Classes: Proper Functioning Condition: Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to: dissipate stream energy associated with high flows, thereby reducing erosion and improving water quality; filter sediment; capture bedload and aid in floodplain development; improve flood-water retention and ground-water recharge; develop root masses that stabilize streambanks; develop diverse ponding and channel characteristics to provide habitat for fish, waterfowl and other uses; and support greater biodiversity.

Functional At Risk: Riparian-wetland areas that are in functional condition, but an existing soil, water, or vegetation attribute makes them susceptible to degradation.

Non-functional: Riparian-wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, and are not reducing erosion, improving water quality, etc.

RASES: Riparian Area Survey and Evaluation System

Reference conditions: We used the concept of historic range of variation to help evaluate whether an ecosystem was functioning properly. Historic range of variation describes how ecosystems, and their characteristics, vary through time and space. Each characteristic changes as a result of varying environmental, age, and disturbance related processes and interacts with other ecosystem characteristics. An appropriate time frame is needed to begin the characterization of the reference period and/or *reference conditions*. The time frame can vary according to what has been recorded and published in the literature. We used existing literature as much as possible to establish reference conditions.

Regeneration: Tree seedling and saplings

Sewage, septic and solid waste dumping: The Forest only has the control and authority to manage its own sewage, septic and solid waste dumping on the Forest. Arizona Department of Environmental Quality is responsible for issuing septic tank permits on private lands, and for managing waste water treatment and effluent from municipalities. The Forest has the authority to control illegal solid waste dumping (trash, cars, appliances, etc.), which occurs to a limited extent. The Forest is limited in its ability to effectively control site specific illegal dumping mainly due to budget and personnel.

Soil condition definitions: Soil condition classes used are Satisfactory, Impaired, Unsatisfactory and Inherently Unstable.

- **Satisfactory**: Indicators signify that soil function is being sustained and soil is functioning properly and normally. The ability of the soil to maintain resource values and sustain outputs is high.
- **Unsatisfactory**: Indicators signify that a loss of soil function has occurred. Degradation of vital soil functions result in the inability of the soil to maintain resource values, sustain outputs or recover from impacts. Unsatisfactory soils are candidates for improved management practices or restoration designed to recover soil functions.
- **Inherently Unstable**: These soils have natural erosion exceeding tolerable limits. Based on the Universal Soil Loss Equation (USLE) these soils are eroding faster than they are renewing but are functioning properly and normally.
- **Impaired**: Indicators signify a reduction in soil function. The ability of the soil to function properly and normally has been reduced and/or there exists an increased vulnerability to degradation. An impaired category indicates there is a need to investigate the ecosystem to determine the cause and degree of decline in soil functions. Changes in land management practices or other preventative measures may be appropriate.

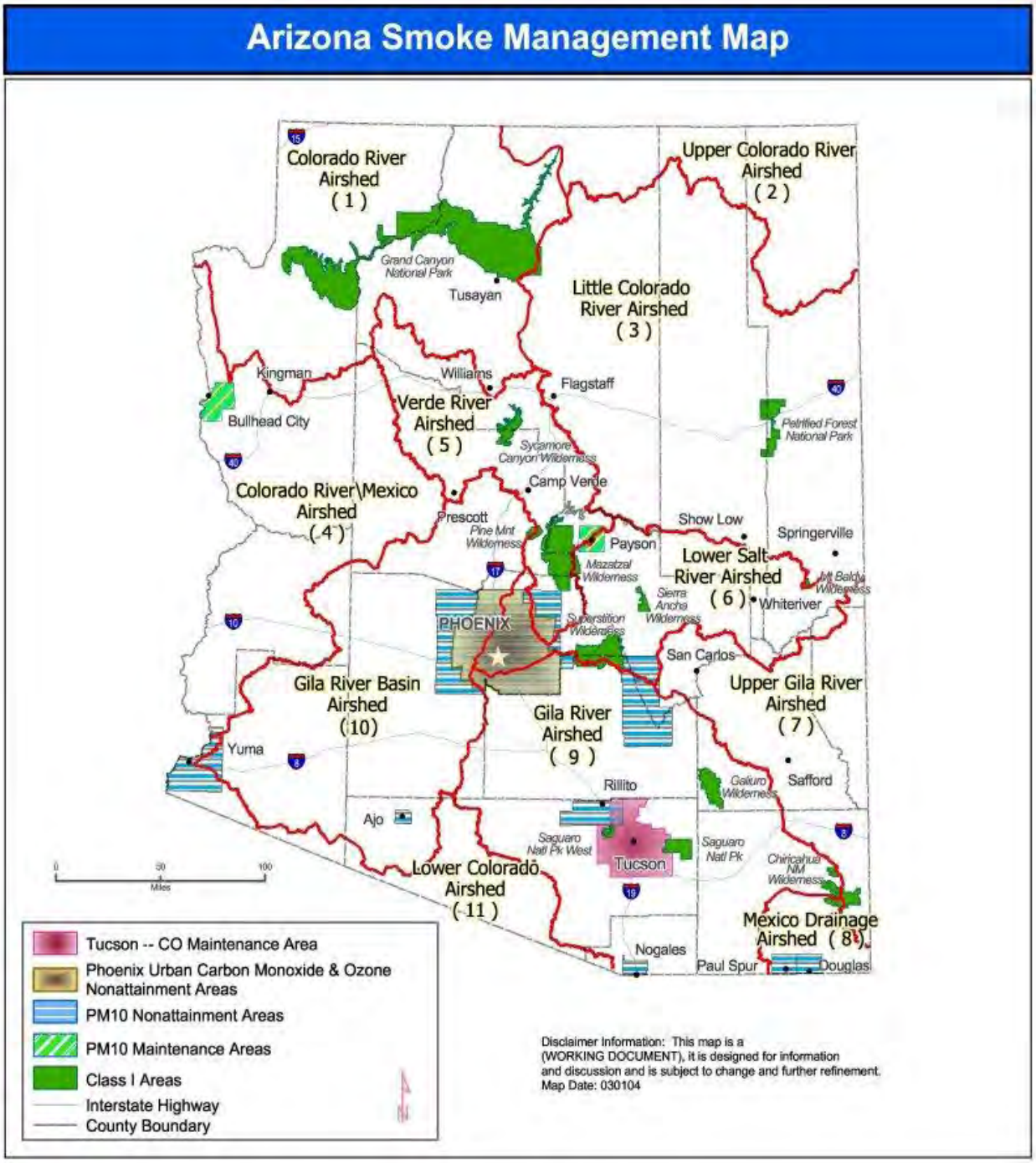
Sustaining ecological systems: The overall goal of the ecological element of sustainability is to provide a framework to contribute to sustaining native ecological systems by providing appropriate ecological conditions to support diversity of native plant and animal species in the plan area. This will satisfy the statutory requirement to provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives.

Water quality categories:

Category 5: The State of Arizona maintains a list of _impaired‘ (Category 5) waters called the 303d list that indicate waters with the most severe water quality problems. It is updated every other year and approved and supplemented by the EPA. These waters are then scheduled for Total Maximum Daily Load (TMDL) assessments. There are strict discharge permit requirements to assure that any new discharges or modifications will not further degrade water quality.
Category 4: —Not Attaining" are those waters where designated use is —not attaining state water quality standards" and have past water quality impairments and current Total Maximum Daily Load (TMDL) plans aimed at improving water quality.
Category 3: Inconclusive. All designated uses are inconclusive. Also, any surface water not assessed due to lack of credible data may be included.
Category 2: Attaining some uses. At least one designated use assessed as _attaining‘ and all other uses assessed as _inconclusive‘.
Category 1: Attaining all uses. All designated uses assess as attaining.

Water withdrawal and well pumping: This is under Forest control within Forest boundaries only. National and regional ground water policy directs Forest well drilling and pumping not to adversely affect connected riparian habitat and water quantity and quality. Arizona Department of Water Quality controls adjacent water withdrawal from current and new wells. The Forest can protest new water withdrawals on major perennial streams where instream flow water rights are procured.

APPENDIX B: SMOKE MANAGEMENT MAP



APPENDIX C: DESCRIPTIONS OF POTENTIAL NATURAL VEGETATION TYPES

Modified from Vander Lee, B. and R. Smith. 2006. Southwest Forest Assessment. Chapter 2: Methods in Ecological and Biological Diversity of National Forests in Region 3.

Alpine Tundra — Alpine conditions begin around 10,600 ft. Alpine areas are typically barren with sparse vegetation including grasses, forbs, lichens and low shrubs. Unstable substrates, exposure to high winds, and short growing season make it difficult for plants to establish and grow in these areas. Barren areas include rocky outcroppings, scree slopes, and open fell-fields. Open fell-fields may include the following species: mountain sandwort (*Arenaria capillaries*), black and white sedge (*Carex albonigra*), Payson's sedge (*Carex paysonis*), Ross's avens (*Geum rossii*), Bellardi bog sedge (*Kobresia myosuroides*), twinflower sandwort (*Minuartia obtusiloba*), Asian forget-me-not (*Myosotis asiatica*), nailwort (*Paronychia pulvinata*), wherry (*Phlox pulvinata*), creeping sibbaldia (*Sibbaldia procumbens*), and moss campion (*Silene acaulis*). Within the alpine region, tundra can be found on gradual to moderate slopes, flat ridges, valleys, and basins, where there is fairly stable soil. The tundra system is typically characterized by low-growing, perennial graminoids and forbs. Rhizomatous, sod-forming sedges are the dominant graminoids, and prostrate and mat-forming plants with thick rootstocks or taproots characterize the forbs. Dominant species include sagebrush (*Artemisia arctica*), sedges (*Carex* spp.), tufted hairgrass (*Deschampsia caespitosa*), fescue grasses (*Festuca* spp.), Ross's avens (*Geum rossii*), Bellardi bog sedge (*Kobresia myosuroides*), wherry (*Phlox pulvinata*), and alpine clover (*Trifolium dasyphyllum*).

Cottonwood Willow Riparian Forest – This system is typically found at lower elevations along rivers and streams in unconstrained valley bottoms. Dominant woody species include cottonwood spp. (*Populus* spp.), willow species (*Salix* spp.), and mesquite spp. (*Prosopis* spp.). Various grasses and forbs are also present. These areas are often subjected to heavy grazing and/or agriculture and can be heavily degraded and the water table can be severely depleted. In addition, many of the areas with this PNVT have experienced an increase in invasive species such as salt cedars (*Tamarix* spp.), and Russian olive (*Elaeagnus angustifolius*). The vegetation is dependent upon on seasonal flooding and high water tables for germination, growth and survivorship of the woody dominants.

Desert Communities – This PNVT spans several types of desert communities, and desert provinces including the Sonoran, Chihuahuan, Great Basin and Mojave. Vegetation types and density will vary with geographic location, precipitation, and topography. Some areas within this PNVT may be barren with an abundance of sand, rock, gravel, scree or talus. Other areas may have sparse to dense vegetation cover that includes succulent species, desert grasses, desert scrub, and some herbaceous cover. Some species occurring in desert communities include: catclaw acacia (*Acacia greggii*), triangleleaf bursage (*Ambrosia deltoidea*), white bursage (*Ambrosia dumosa*), mesquite (*Prosopis* spp.), desert ironwood (*Olneya tesota*), saltbush (*Atriplex* spp.), creosote (*Larrea tridentate*), iodine bush (*Allenrolfea occidentalis*), splitleaf brickellia (*Brickellia laciniata*), desert broom (*Baccharis sarothroides*), desert willow (*Chilopsis*

linearis), Apache plume (*Fallugia paradoxa*), cheesebush (*Hymenoclea salsola*), barrel cactus (*Ferocactus* spp.), hedgehog cacti (*Echinocereus spp.*), cholla and prickly pear (*Opuntia* spp.) saguaro (*Carnegia gigantean)*, salt grass (*Distichlis spicata*), rice grasses (*Oryzopsis* spp.), and dropseed grasses (*Sporobolus* spp.).

Great Basin Grassland is a combination of Great Plains Grassland and Great Basin/Colorado Plateau Grassland and Steppe for the purposes of this assessment.

- **Great Plains Grassland** (called Great Basin Grassland in this assessment) This PNVT is characterized by mixed grass to tall grass prairie found on moderate to gentle slopes. Rain, temperature and soils limit this PNVT to lower elevations. This PNVT is mostly dominated by one or some of the following species: big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), mountain muhly (*Muhlenbergia montana*), green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*), sand dropseed (*Sporobolus cryptandrus*), blue grama (*Bouteloua gracilis*), needle and thread grass (*Hesperostipa comata*), or New Mexico feathergrass (*Hesperostipa neomexicana*). This PNVT may also include areas that are dominated by low cover grasses and forbs.

- **Great Basin / Colorado Plateau Grassland and Steppe**– In general, this PNVT is found at lower elevations with vegetation coverage consisting of mostly grasses and interspersed shrubs. Grass species may include but are not limited to: Indian ricegrass (*Achnatherum hymenoides*), threeawn spp. (*Aristida*spp.), blue grama (*Bouteloua gracilis*), fescue spp. (*Festuca* spp.), needle and thread grass (*Hesperostipa comata*), spike fescue (*Leucopoa kingii*), *Muhlenbergia* spp., James‘ galleta (*Pleuraphis jamesii*), and Sandberg bluegrass (*Poa secunda*). Shrub species may include but are not limited to: sagebrush (*Artemesia tridentate* spp.), saltbush (*Atriplex* spp.),*Ephedra*, snakeweed (*Gutierrezia)*, winterfat

Interior Chaparral – This PNVT is typically found on mountain foothills and lower slopes where low-elevation desert landscapes transition into wooded evergreens. Interior chaparral consists of mixed shrub associations including but not limited to the following species: Manzanita spp. (*Arctostaphylos* spp.), crucifixion thorn (*Canotia holacantha*), desert ceanothus (*Ceanothus greggii*), mountain mahogany (*Cercocarpus montanus*), little-leaved mountain mahogany (*Cercocarpus intricatus*), Antelope bushes (*Purshia* spp.), silktassles (*Garrya spp.*), Stansbury cliffrose (*Purshia stansburiana*), shrub live oak (*Quercus turbinella*), and sumacs (*Rhus* spp.)

Piñon Juniper Evergreen Shrub – For the purposes of this assessment, this PNVT is a combination of two PNVTs - Madrean Encinal Woodland and Madrean Pine-Oak Woodland. The term Piñon Juniper Evergreen Shrub more accurately describes this type on the Forest.

Madrean Encinal Woodland - Found in the Madrean Province, this PNVT occurs on foothills, canyons, bajadas and plateaus between the semi-desert grasslands and Madrean pine-oak woodlands. This PNVT is dominated by Madrean evergreen oaks such as Arizona white oak (*Quercus arizonica*), Emory oak (*Quercus emoryi*), gray oak (*Quercus grisea*), Mexican blue oak (*Quercus oblongifolia*), and Toumey oak (*Quercus toumeyi*). Madrean pine, Arizona cypress, Piñon and juniper trees and interior chaparral species may be present, but do not co-

dominate. The ground cover is dominated by warm-season grasses such as threeawns (*Aristida spp*.), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), Rothrock grama (*Bouteloua rothrockii*), Arizona cottontop (*Digitaria californica*), plains lovegrass (*Eragrostis intermedia*), curly-mesquite (*Hilaria belangeri*), green sprangletop (*Leptochloa dubia*), muhly grasses (*Muhlenbergia spp*.), or Texas bluestem (*Schizachyrium cirratum*).

Madrean Pine-Oak Woodland – Found in the Madrean province, this PNVT is dominated by open to closed canopy of evergreen oaks such as Arizona white oak (*Quercus arizonica*), alligator juniper (*Juniperus deppeana*), Chihuahua pine (*Pinus leiophylla*) and other various pines with a grassy understory. Madrean pine-oak woodlands usually occupy foothills and mountains ranging from approximately 4,000 to 7,000 ft. in elevation. The climate where this PNVT is found generally consists of mild winters and wet summers with mean annual precipitation ranging from about 10 to 25 inches; half of the precipitation typically occurs in summer, with the remainder occurring during the winter and spring.

Mixed Broad Leaf Deciduous Riparian Forest – Located in the Madrean and Chihuahuan provinces, mixed broadleaf deciduous riparian forests are found along rivers and streams starting at low elevations (approximately 4,000 ft.) and climbing up to montane elevations of approximately 9,000 ft. The vegetation is a mix of riparian woodlands and shrublands with a variety of vegetation associations. The dominant vegetation is likely to depend upon a suite of site-specific characteristics including elevation, substrate, stream gradient, and depth to groundwater. For example, one vegetation association is dominated by bigtooth maple with mixed stands of Gambel oak, some scattered conifers and possibly some quaking aspen (*Populus tremuloides*). Other sites can be dominated by a mixture of the following woody species: boxelder, narrowleaf cottonwood, Fremont cottonwood (*Populus fremontii*), Arizona sycamore (*Platanus wrightii*), velvet ash (*Fraxinus velutina*), Arizona walnut (*Juglans major*), Arizona cypress (*Cupressus arizonica*) and willows (*Salix exigua* and others). The forest often contains oaks (*Quercus gambelii, Q. emoryi, Q. arizonica*) and conifers (*P. ponderosa, Juniperus deppeana*) from upstream and adjacent uplands. Exotic species such as Russian olive (*Elaeagnus angustifolia*) and salt cedar (*Tamarix* spp.) are common in some stands, especially at lower elevations. Vegetation can be dependent upon annual or periodic flooding for growth and reproduction, especially at lower elevations.

Mixed Conifer Forest – Mixed Conifer and Aspen Forest and Woodland PNVTs were combined for the purpose of this assessment.

- Mixed conifer spans a variety of dominant and co-dominant species in both dry and mesic environments in the Rocky Mountain and Madrean Provinces. In the Rocky Mountains, montane conifer forests may be found at elevations between 5,000 and 10,000 ft., situated between ponderosa pine, pine-oak, or Piñon-juniper woodlands and spruce-fir or sub-alpine conifer forests. Dominant and co-dominant vegetation varies in elevation and moisture availability. In the lower and drier elevation portions within this PNVT, Gambel oak (*Quercus gambelii*) and ponderosa pine (*Pinus ponderosa*) may co-dominate. In higher and more mesic areas ponderosa pine may co-dominate with Douglas fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*). Other vegetation that may be present but does not co-dominate in these higher and mesic areas include Englemann spruce (*Picea engelmannii*) and Colorado blue spruce (*Picea pungens*). In the Madrean

Province, this PNVT can be characterized by large and small-patch forests and woodlands dominated by Douglas fir or white fir with Madrean oaks such as silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Quercus rugosa*). The understory vegetation is comprised of a wide variety of shrubs, grasses, graminoids (sedges, etc.), and forbs; the compositions depends on soil type, aspect, elevation, disturbance history and other factors.

- **Aspen Forest and Woodland** —Aspen forest and woodlands are found in montane and sub-alpine zones at elevations ranging from approximately 5,000 to10, 000 ft., but occasionally at lower elevations in some areas. These upland forests and woodlands are dominated by quaking aspen (*Populus tremuloides*) and may or may not have a significant conifer component, depending upon successional status. The understory structure may have shrubs and an herbaceous layer, or just an herbaceous layer. The herbaceous layer may be dense or sparse, dominated by graminoids or forbs. Some of the species typically found associated with aspen include Arizona peavine (*Lathyrus arizonica*), meadow rue (*Thalictrum fendleri*), deer‘s ears (*Swertia radiata*), yarrow (*Achillea lanulosa*), violet (*Viola canadensis*), paintbrush (*Castilleja* spp.), arnica (*Arnica montanum*), and several grasses and sedges (*Poa spp.* and *Carex* spp.). Distribution of this PNVT is limited by several factors including soil type, adequate soil moisture required to meet its high evapotranspiration demand, the length of the growing season or low temperatures, and major disturbances that clear areas of vegetation and stimulate root sprouting and colonization.

Montane/Subalpine Grassland – For the purposes of this assessment, montane and subalpine grasslands were combined.

- This PNVT is typically found at sub-alpine elevations (9,000 ft. and higher) on gentle to moderate gradient slopes. Soils are usually moist throughout the year. Dominant vegetation cover includes forbs with some graminoids. Common species found in this PNVT include but are not limited to: fleabane spp. (*Erigeron* spp.), asters (*Asteraceae* spp.), bluebells (*Mertensia* spp.), *Penstimon* spp., lupine spp. (*Lupinus* spp.) and goldenrods (*Solidago* spp.).

- **Sub-alpine Grassland -** Also referred to as montane grasslands and was included in the Montane Subalpine Grassland PNVT for this assessment, this system occurs at elevations ranging from 8,000-11,000 ft., and often harbors several plant associations with varying dominant grasses and herbaceous species. Such dominant species may include Parry‘s oatgrass (*Danthonia parryi*), Arizona fescue (*Festuca arizonica*), Thurber‘s fescue (*Festuca thurberi*), pine dropseed (*Blepharoneuron tricholepis*), Kentucky bluegrass (*Poa pratensis*), small camas (*Camassia quamash*), various sedges (*Carex* spp.), shooting star (*Dodecatheon jeffreyi*), fowl manna grass (*Glyceria striata*), Sierra rush *(Juncus nevadensis*), Rocky Mountain iris (*Iris missouriensis*), Parry‘s bellflower (*Campanula parryi*), California false hellebore (*Veratrum californicum*), and bulrush spp. (*Scirpus* and/or *Schoenoplectus* spp). Trees may occur along the periphery of the meadows, which may include southwestern white pine (*Pinus strobiformis*), Engelmann spruce (*Picea engelmannii*), and sub-alpine fir (*Abies lasiocarpa*). Some shrubs may also be present.

These meadows are seasonally wet, which is closely tied to snowmelt. They typically do not experience flooding events.

Montane Willow Riparian Forest – This PNVT stretches along various elevational gradients from lower elevations (3,500 ft.) in mountain canyons and valleys to higher mountainous elevations (10,000ft.). At lower elevations this PNVT can be found along perennial and seasonally intermittent streams. Here, the dominant woody vegetation includes cottonwood spp. (*Populus* spp.), Arizona sycamore (*Platanus wrightii*), Arizona Walnut, (*Juglans major*), velvet ash (*Fraxinus velutina*), and soapberry (*Sapindus saponaria*). Shrubs include willow spp. (*Salix* spp.), cherry (*Prunus* spp.) and Arizona alder (*Alnus oblongifolia*). At higher elevations, this PNVT is found along streambanks, seeps, fens, and isolated springs. At higher elevations, this PNVT are shrub and herb dominated. Dominant shrubs include alder spp. (*Alnus* spp.), birch spp. (*Betula* spp.), redosier dogwood (*Cornus sericea*), and a variety of willow spp. (*Salix* spp.).

Piñon-Juniper Woodland – This PNVT is mostly found on lower slopes of mountains and in upland rolling hills at approximately 4,500 to 7,500 ft. in elevation. Most common Piñon pine is the Colorado Piñon (*Pinus edulis*), with singleleaf Piñon (*Pinus monophylla*) occurring in limited areas. One-seed juniper (*Juniperus monosperma*) is most common in Arizona and New Mexico; however, there are areas with Utah juniper (*Juniperus osteosperma*) and Rocky Mountain juniper (*Juniperus scopulorum*). In addition, annual and perennial grasses and graminoids, forbs, half-shrubs and shrubs can be found beneath the woodland overstory.

Ponderosa Pine – The ponderosa pine forest is widespread in the Southwest occurring at elevations ranging from 6,000-9,000 ft on igneous, metamorphic, and sedimentary parent soils with good aeration and drainage, and across elevational and moisture gradients. The dominant species in this system is Ponderosa pine (*Pinus ponderosa*). Other trees, such as Gambel oak (*Quercus gambelii*), Douglas-fir (*Pseudotsuga menziesii*), Piñon pine (*Pinus edulis*), and juniper spp. (*Juniperus* spp.) may be present. There is typically a shrubby understory mixed with grasses and forbs, although this type sometimes occurs as savannah with extensive grasslands interspersed between widely spaced clumps or individual trees. This system is adapted to drought during the growing season, and has evolved several mechanisms to tolerate frequent, low intensity surface fires.

Semi-desert Grassland – Semi-desert grassland occurs throughout southeastern Arizona and southern New Mexico at elevations ranging from 3,000 to 4,500 ft. These grasslands are bounded by Sonoran or Chihuahuan desert at the lowest elevations and woodlands or chaparral at the higher elevations. Species composition and dominance varies across the broad range of soils and topography that occur within the two states. Dominant grassland associations/types are black grama (*Bouteloua eriopoda*) grassland, blue grama (*Bouteloua gracilis*) grassland, tobossa (*Hilaria mutica*) grassland, giant sacaton (*Sporobolus wrightii*) grassland, mixed native perennial grassland, and non-native perennial grassland. Shrubs also occupy these grasslands and their abundance and species composition also varies.

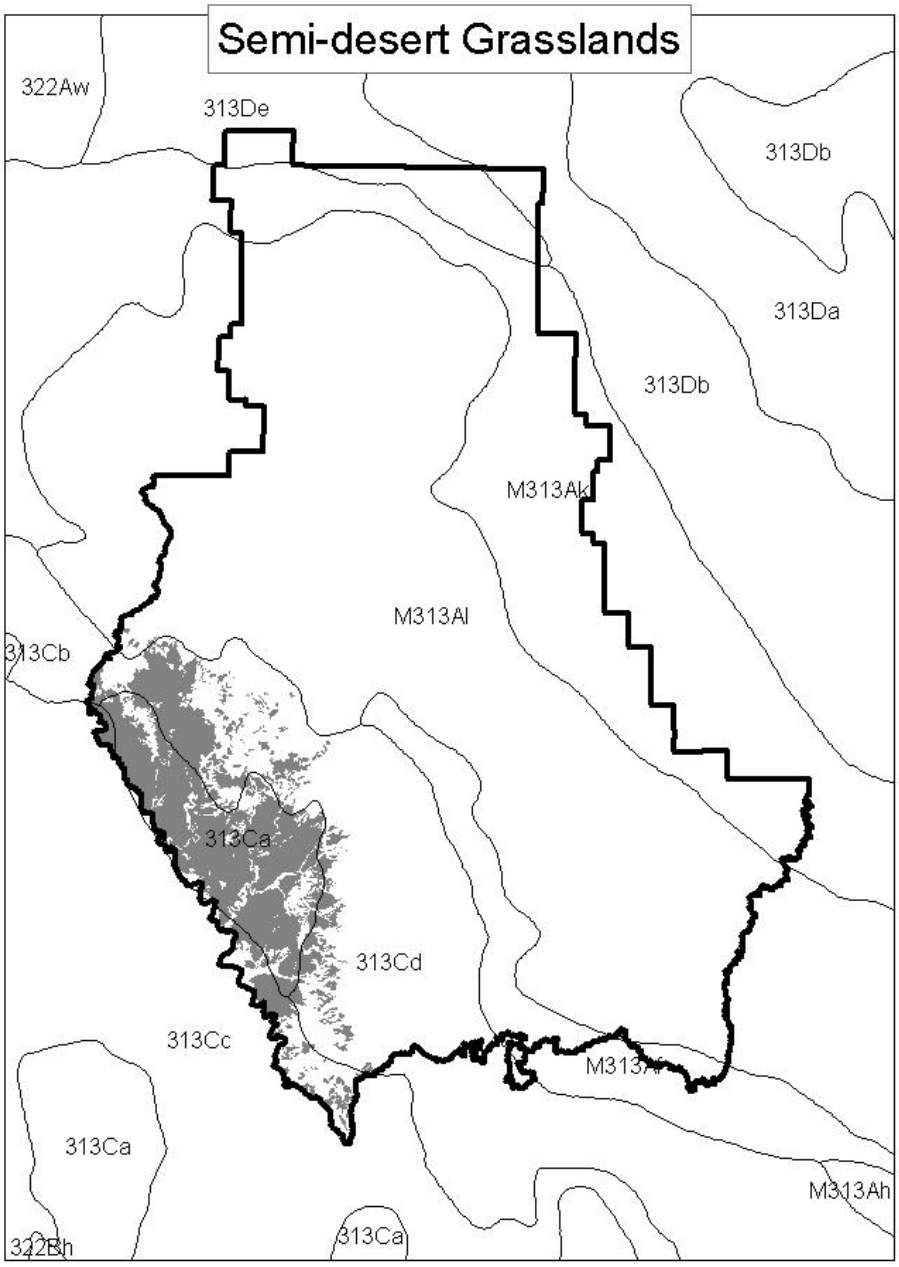
Spruce-fir Forest – Also known as sub-alpine conifer forests, spruce-fir forests range in elevation from 9,000 to 11,500 ft. along a variety of gradients including gentle to very steep mountain slopes. Englemann spruce (*Picea engelmannii*) and sub-alpine fir (*Abies lasiocarpa*) or corkbark fir (*Abies lasiocarpa* var. *lasiocarpa*) dominate this PNVT either mixed or alone.

Douglas-fir (*Pseudotsuga menziesii*) along with mixed conifer and quaking aspen (*Populus tremuloides*) stands may also be present in this system for long periods without regeneration. Herbaceous species may include but are not limited to red baneberry (*Actaea rubra*), starry false Solomon‘s seal (*Maianthemum stellatum*), fleabane (*Erigeron eximius*), blackberry (*Rubus pedatus*), and sub-alpine lupine (*Lupinus arcticus* spp. *Subalpinus*). Natural disturbances in this PNVT are blow-downs, insect outbreaks and stand replacing fires.

Wetland/Cienega – This PNVT is associated with perennial springs or headwater streams where groundwater intersects the surface and creates pools of standing water, sometime with channels flowing between pools. Often soils in the area are highly saline. Distribution and types of vegetation vary due to a gradient in saturated soils and salinity. Some vegetation types found in wetland/cienegas include salt grass (*Distichlis spicata*), yerba mansa (*Anemopsis californica*), and sacaton in more saline areas; in saturated soils are rushes, sedges, flat sedges and spike rushes and deep pools support a variety of aquatic vegetation. This PNVT also includes high elevation (3,500 – 11,000 ft.) meadows with subsurface flows dominated by herbaceous cover.

APPENDIX D: PNVT MAPS

These large-scale maps of major PNVTs go from low to high elevation. The Forest boundary is shown in black and subsection lines are shown in gray. Gray shading within the Forest shows the boundary of the PNVT. PNVTs with minor extent on the Forest are not displayed because they are too small or scattered to show at this scale.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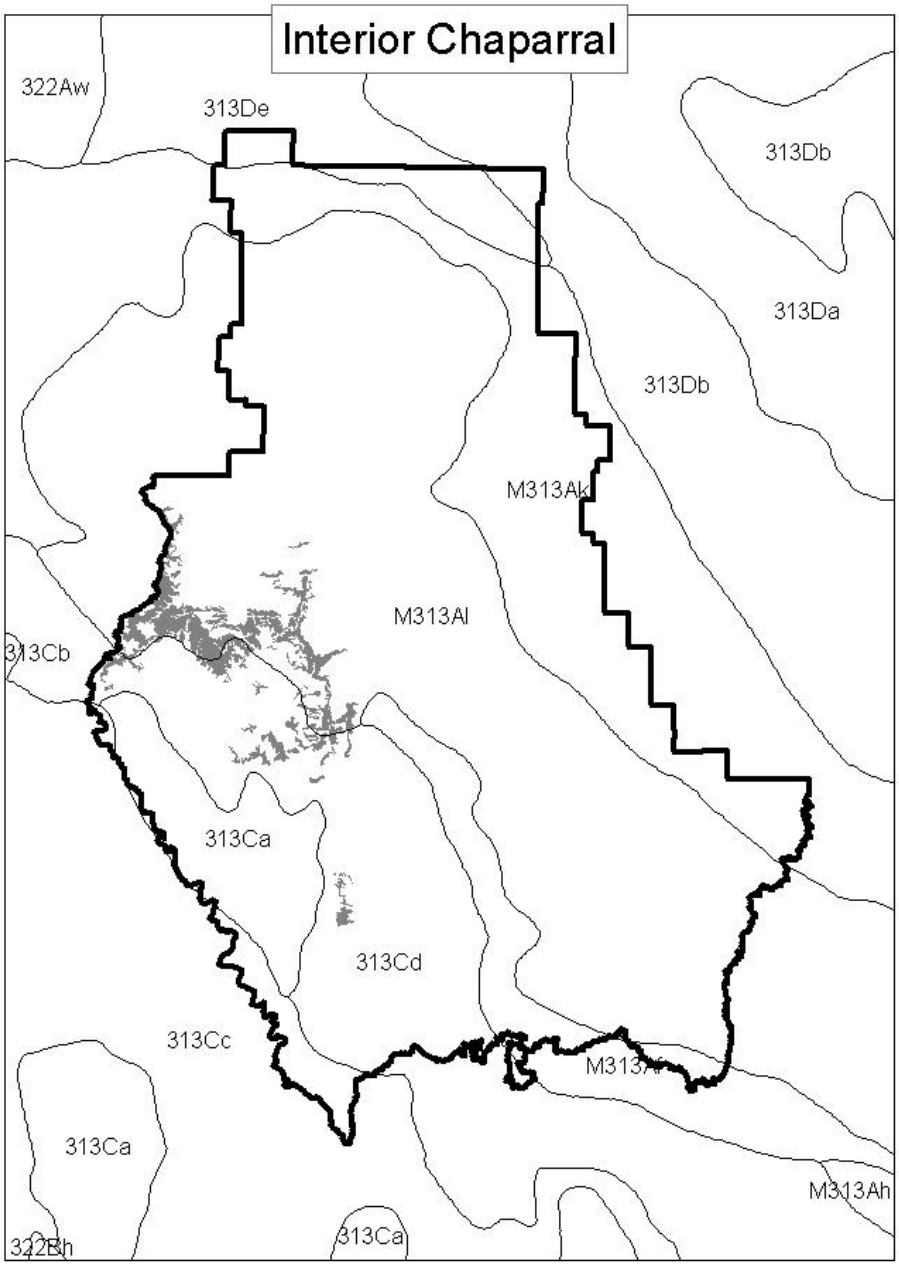
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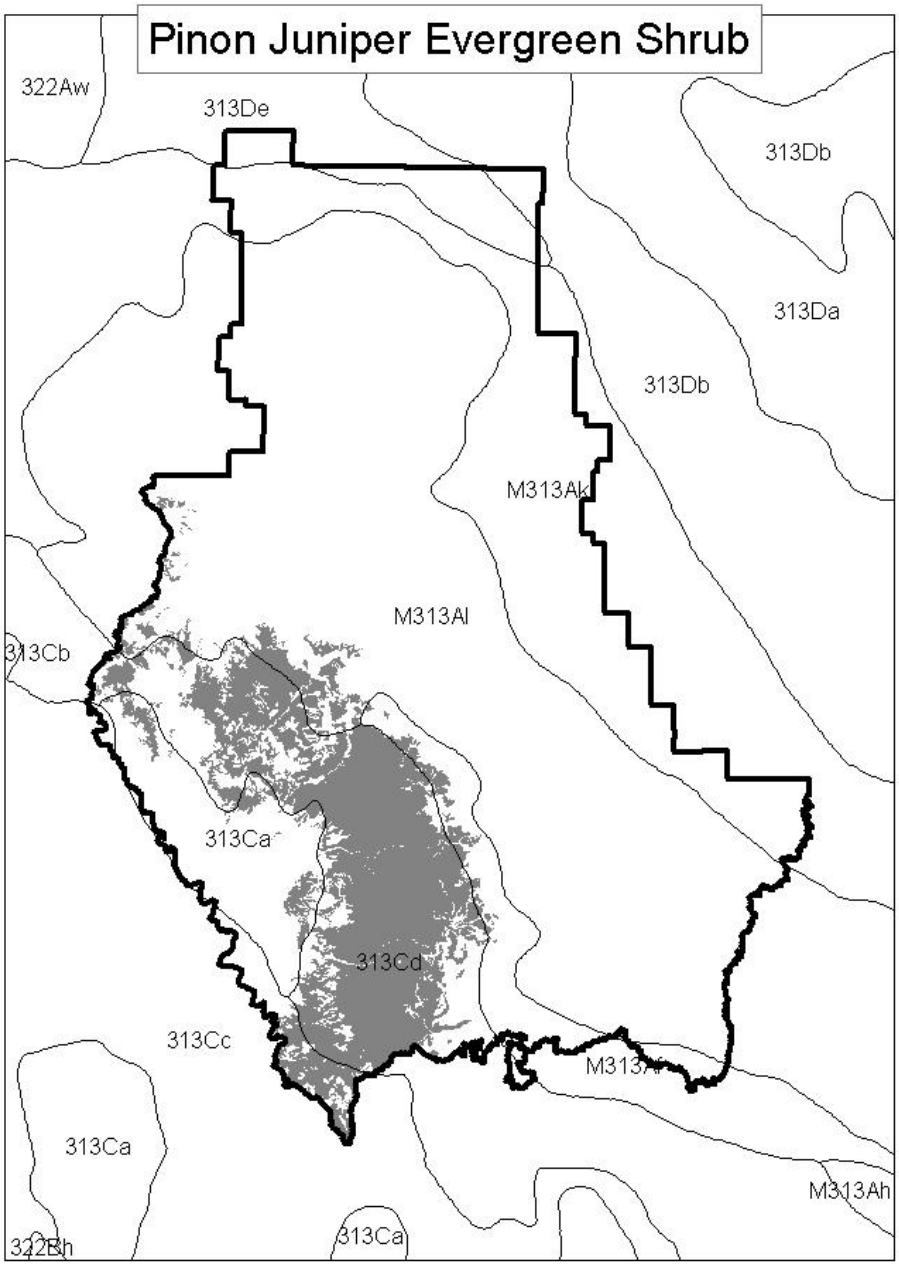
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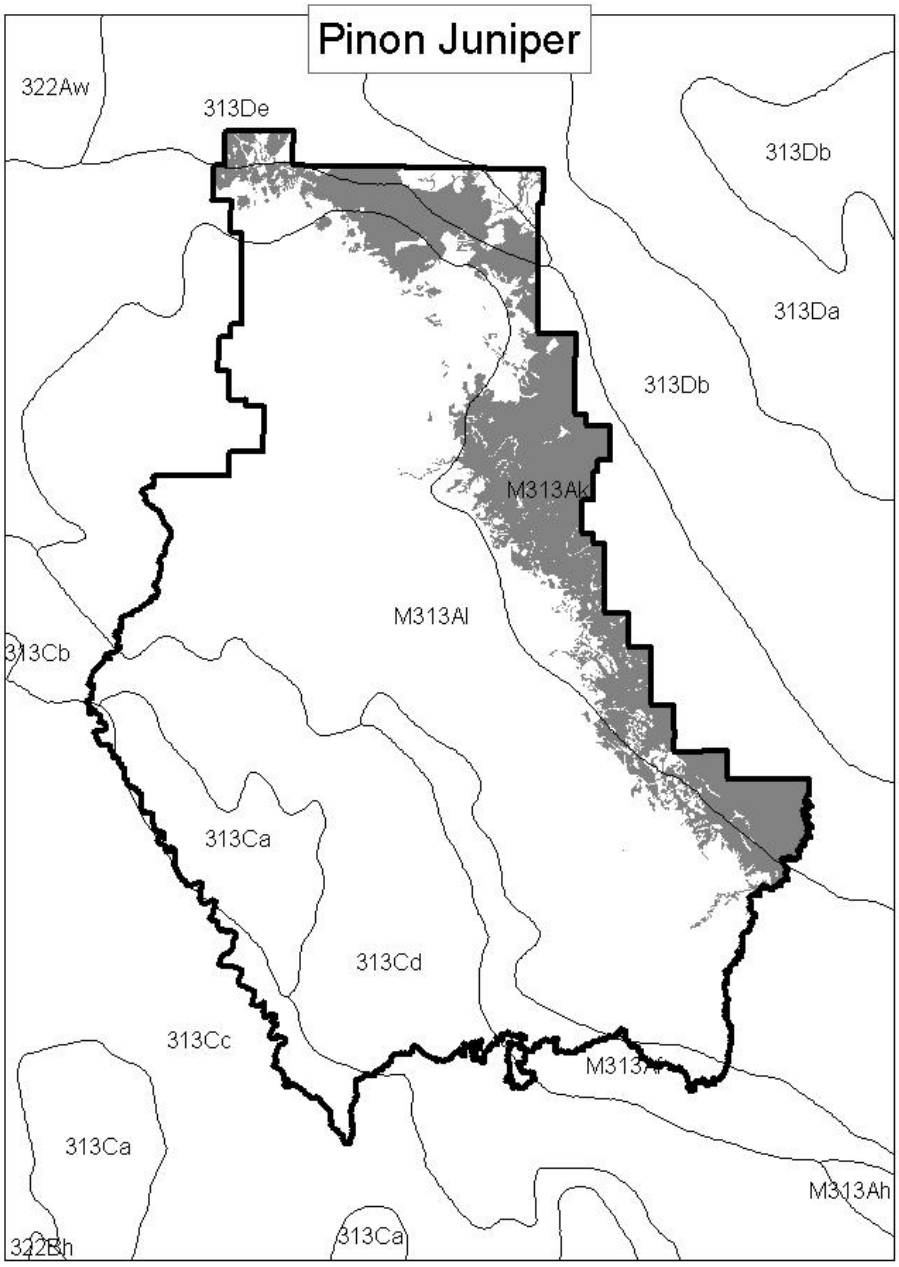
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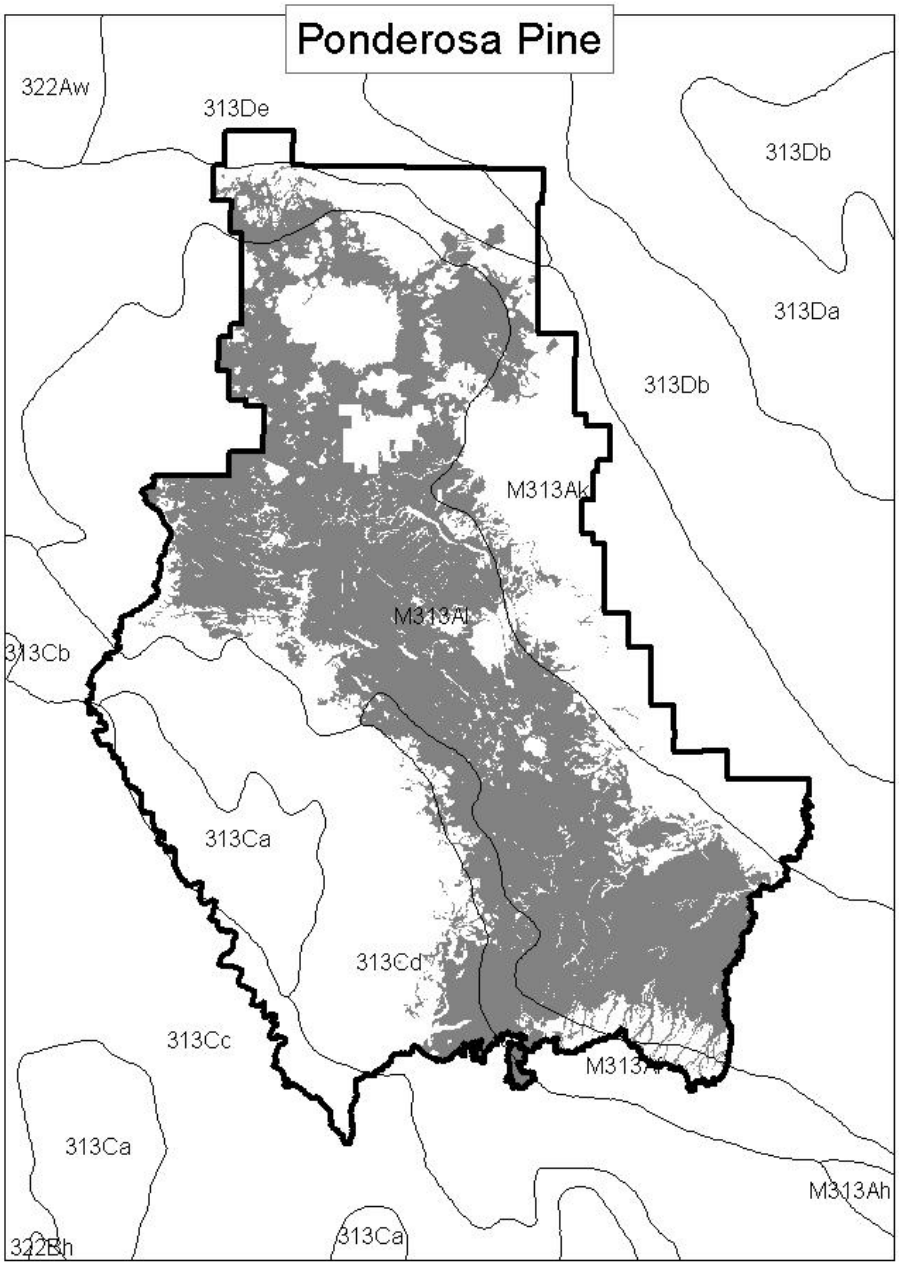
Ponderosa Pine
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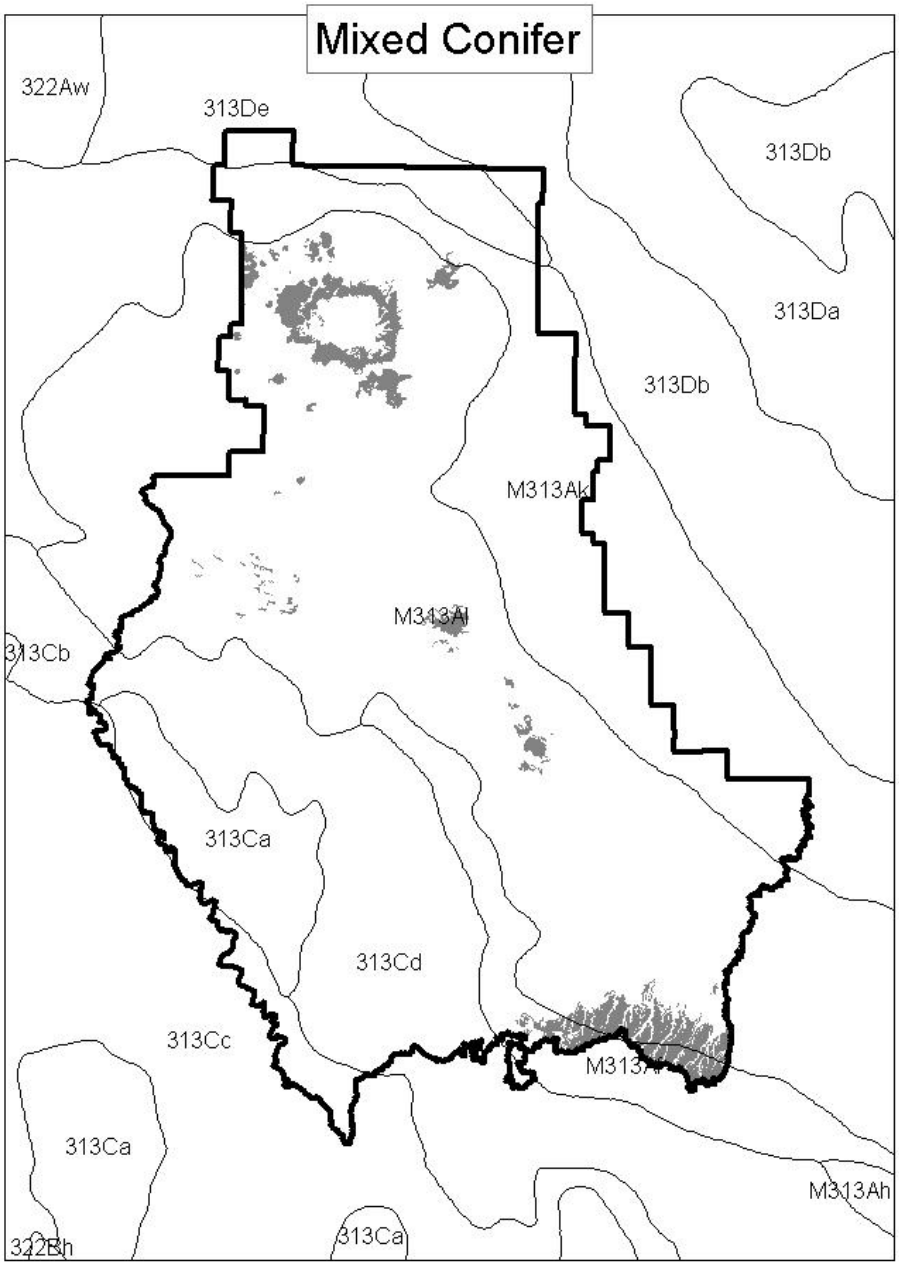
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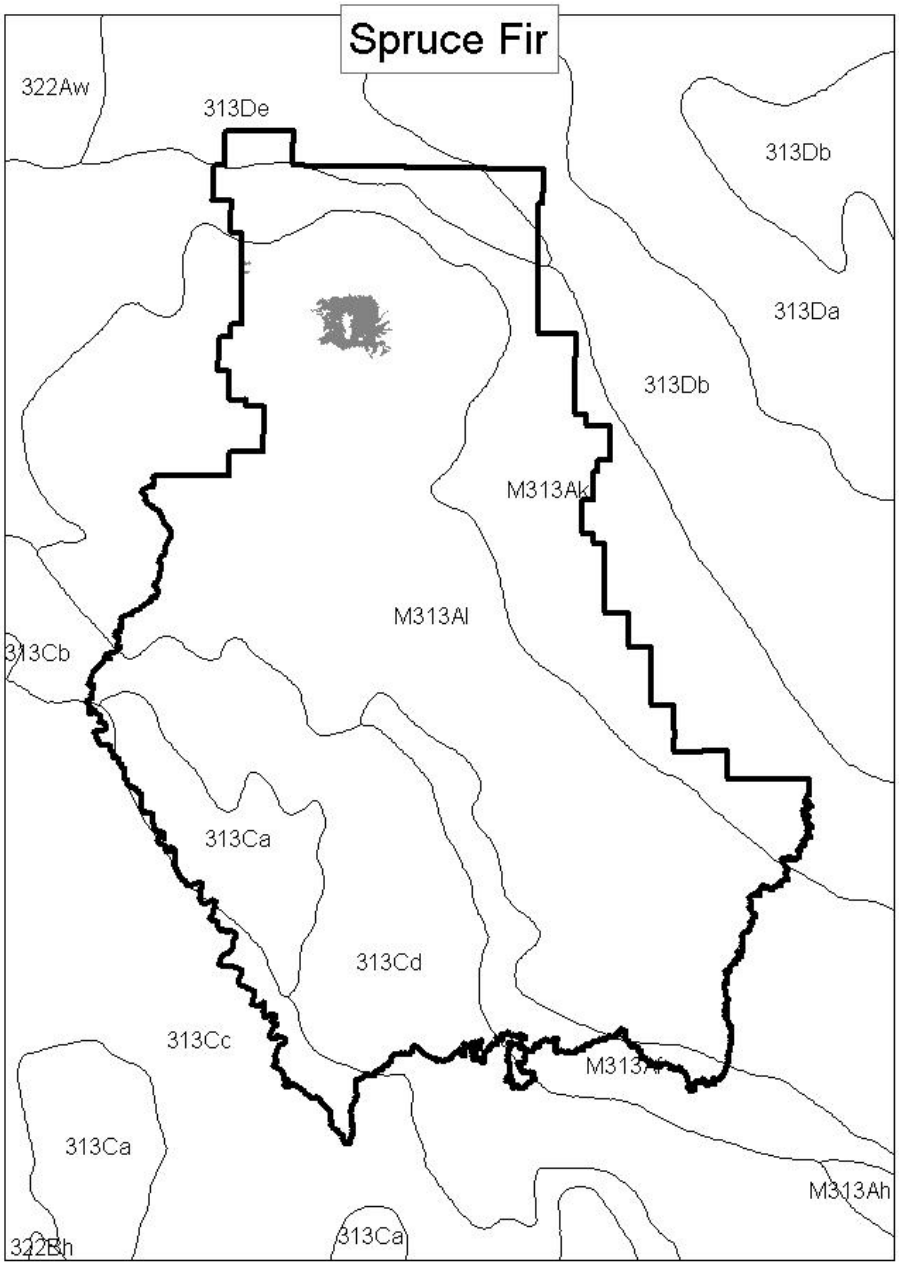
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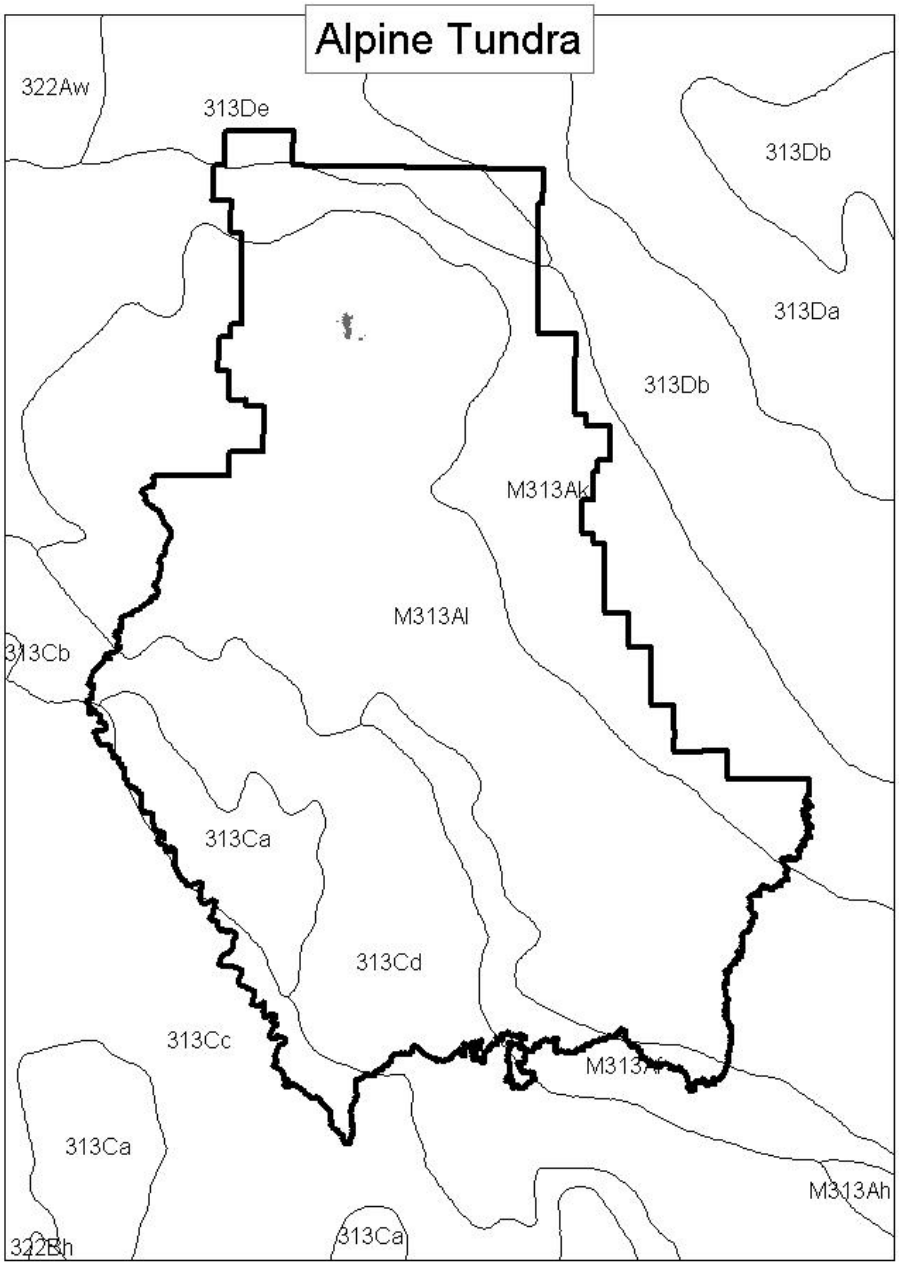
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APPENDIX E: CURRENT, REFERENCE AND PROJECTED FUTURE SOIL CONDITION

PNVT	Reference and Current Soil Condition	Projected Future (PF) Soil Condition & Trends (Is Current management moving condition towards, or away from reference condition or static?	Comparison of Reference and Current Condition
Cottonwood Willow Riparian Forest	Reference condition is satisfactory. Current erosion, hydrologic and nutrient cycling functions are, impaired,	Most areas towards, some away. In most areas litter and species diversity are improving fairly rapidly since riparian areas are resilient and rapid in recovery. Impaired soils are projected to move towards satisfactory. Removal of livestock grazing along the Verde River is moving this area towards reference conditions. Most other areas are still departed appreciably from reference conditions but moving towards reference conditions. Some high recreation impacted areas are moving away from reference conditions and are projected to be impaired and unsatisfactory.	High departure between reference to current conditions. Projected future litter and vegetation conditions (nutrient cycling function) should improve and approach reference conditions under current grazing management as long as Allotment Management Plans allowable use levels are met.
Desert Communities	Reference condition is satisfactory. Current condition unsatisfactory due to declined nutrient cycling and erosion functions.	Static Would take a couple of decades to improve appreciably towards satisfactory due to high level of disturbance and limited annual precipitation received.	High departure from reference conditions. Overall soil condition to remain static especially if drought persists.

PNVT	Reference and Current Soil Condition	Projected Future (PF) Soil Condition & Trends (Is Current management moving condition towards, or away from reference condition or static?	Comparison of Reference and Current Condition
Montane / Subalpine Grassland	Montane portion: Relatively large amounts of impaired soils currently where reference conditions had satisfactory soils. Subalpine: currently satisfactory.	Static (similar to current, projected to have impaired soils) for Montane portion. Cannot control elk grazing. Static (similar to current, projected to have satisfactory soil conditions) for Subalpine portion.	High departure between reference and current conditions on Montane portions. Low departure between reference and current condition on Subalpine portion.
Ponderosa Pine Forest	Overall satisfactory but nutrient cycling function is borderline impaired/satisfactory.	Very slowly towards It would take a couple of decades to treat impaired soils under current management and implementation rate. Nutrient cycling function would improve to satisfactory in treated areas Soil condition would remain static or decline in untreated areas and pose substantial risk to watershed function and soil productivity due to increased risk from severe wildfire These untreated soils are projected to become impaired and unsatisfactory. Thinning, fire-use prescribed fire treatments should improve nutrient cycling function where it occurs but would take decades to improve the entire PNVT	Low departure from reference conditions. However, there is a departure between reference and current impaired soil conditions.

PNVT	Reference and Current Soil Condition	Projected Future (PF) Soil Condition & Trends (Is Current management moving condition towards, or away from reference condition or static?	Comparison of Reference and Current Condition
Semi-Desert Grassland	Reference conditions had satisfactory soils. Currently, relatively large amounts of impaired and unsatisfactory soils. Nutrient cycling (litter, organic matter and compaction) has declined.	Slowly towards. Where Forest Plan objectives for soils are met, litter and species diversity to slowly improve. Unsatisfactory soils are projected to slowly improve towards impaired and impaired towards satisfactory. It may take a long time due to limited annual precipitation received. Current grazing strategies and restricted cross-country OHV travel should slowly improve soil nutrient cycling functions but could remain static with continued drought.	Moderate departure from reference soil conditions.
Wetland / Cienega	Reference conditions had satisfactory soils. Current condition has high amounts of unsatisfactory soils and.	Mostly static. Projected to be similar to current, unsatisfactory and to remain the same as long as unrestricted elk grazing continues. Following Plan desired conditions is not projected to be sufficient to improve unsatisfactory soils towards satisfactory. Livestock and elk excluded wetlands would trend rapidly towards satisfactory soil conditions.	High departure from reference soil conditions.

PNVTs not listed have static or upward trend. Great Basin Grasslands have notable departure between reference and current conditions but are projected to be moving towards reference condition under current management. Ponderosa Pine has variable trend depending on treatments where areas of static to downward trend are based on lack of herbaceous vegetation but do not affect the ability of the soil to produce. PNVTs listed have downward soil productivity signifying an ecological need for change.

APPENDIX F: SPECIES LIST

This is a list of species carried forward for the Coconino NF Plan Revision Process with U.S. Fish and Wildlife Service and Southwestern Region Forest Service status

FS Sensitive = on Southwestern Regional Forester's Sensitive Species List
Candidate = a candidate for listing under Endangered Species Act but listing is precluded by other priorities
Endangered = in danger of becoming extinct
Threatened = in danger of becoming endangered
Endangered XN = Experimental nonessential population
Blank = Forest planning species

Birds **18**		
Accipiter gentilis	Northern goshawk	FS Sensitive
Aechmophorus clarkia	Clark's grebe	FS Sensitive
Athene cunicularia hypugaea	Western burrowing owl	FS Sensitive
Buteo regalis	Ferruginous hawk	FS Sensitive
Buteogallus anthracinus	Common black hawk	FS Sensitive
Catharus ustulatus	Swainson's thrush	
Coccothraustes vesperinus	Evening grosbeak	
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	Candidate/FS Sensitive
Empidonax traillii extimus	Southwestern willow flycatcher	Endangered
Falco peregrinus anatum	American peregrine falcon	FS Sensitive
Gymnogyps californianus	California condor	Endangered XN
Haliaeetus leucocephalus	Bald eagle	FS Sensitive
Haliaeetus leucocephalus pop. 3	Bald eagle	Threatened
Oporonis tolmiei	MacGillivray's warbler	
Pipolo aberti	Abert's towhee	FS Sensitive
Rallus longirostris yumanensis	Yuma clapper rail	Endangered
Regulus satrapa	Golden-crowned kinglet	
Strix occidentalis lucida	Mexican Spotted Owl	Threatened
Fish **15**		
Agosia chrysogaster	Longfin dace	FS Sensitive
Catostomus clarki	Desert sucker	FS Sensitive
Catostomus discobolus	Bluehead sucker	FS Sensitive
Catostomus insignis	Sonora Sucker	FS Sensitive
Catostomus sp. 3	Little Colorado Sucker	FS Sensitive
Gila intermedia	Gila Chub	Endangered
Gila nigra	Headwater Chub	Candidate/FS Sensitive
Gila robusta	Roundtail Chub	Candidate/FS Sensitive
Lepidomeda vittata	Little Colorado Spinedace	Threatened

Meda fulgida	Spikedace	Threatened
Oncorhynchus gilae gilae	Gila Trout	Threatened
Poeciliopsis occidentalis occidentalis	Gila topminnow	Endangered
Ptychocheilus lucius	Colorado Pikeminno	Endangered XN
Tiaroga cobitis	Loach Minnow	Threatened
Xyrauchen texanus	Razorback sucker	Endangered
Amphibians & Reptiles 8		
Bufo microscaphus	Arizona toad	FS Sensitive
Heloderma suspectum suspectum	Gila monster	FS Sensitive
Kinosternon sonoriense	Sonora mud turtle	
Lithobates chiricahuensis	Chiricahua Leopard Frog	Threatened
Lithobates pipiens	Northern leopard frog	FS Sensitive
Lithobates yavapaiensis	Lowland leopard frog	FS Sensitive
Thamnophis eques	Northern Mexican gartersnake	FS Sensitive
Thamnophis rufipunctatus	Narrow-headed gartersnake	Candidate/FS Sensitive
Invertebrates 33		
Acrolophitus nevadensis	Nevada Pointed-headed Grasshopper	
Aeshna persephone	Persephone's Darner	
Anacroneuria wipukupa	A Stonefly	
Anodonta californiensis	California Floater	FS Sensitive
Apatania arizona	A Caddisfly	
Atopsyche sperryi	A Caddisfly	
Atopsyche tripunctata	A Caddisfly	
Baetodes arizonensis	A mayfly	
Ceratopsyche venada	A Caddisfly	
Chimarra primula	A Caddisfly	
Cicindela oregona maricopa	Maricopa Tiger Beetle	
Culoptila kimminsi	A Caddisfly	
Culoptila moselyi	A Caddisfly	
Ithytrichia mexicana	A Caddisfly	
Lepidostoma knulli	A Caddisfly	
Nectopsyche dorsalis	A Caddisfly	
Ochrotrichia ildria	A Caddisfly	
Oeneis alberta daura	Alberta Arctic	
Ophiogomphus arizonicus	Arizona Snaketail	
Piruna polingi	Four-spotted Skipperling	FS Sensitive
Polycentropus arizonensis	A Caddisfly	
Polycentropus gertschi	A Caddisfly	

Protoptila balmorhea	Balmorhea Saddle-case Caddisfly	
Pyrgulopsis morrisoni	Page springsnail	Candidate/FS Sensitive
Pyrgulopsis simplex	Fossil Springsnail	FS Sensitive
Radiodiscus millecostatus	Ribbed Pinwheel	
Smicridea dispar	A Caddisfly	
Sonorella coltoniana	Walnut Canyon Talussnail	
Sonorella compar	Oak Creek Talussnail	
Sonorella micromphala	Milk Ranch Talussnail	
Speyeria nokomis nitocris	Nitocris Fritillary	FS Sensitive
Speyeria nokomis nokomis	Nokomis Fritillary	FS Sensitive
Wormaldia arizonensis	A Caddisfly	
Mammals 16		
Antilocapra americana	Pronghorn	
Canus lupus baileyi	Mexican Gray Wolf	Endangered XN
Castor canadensis	Beaver	
Corynorhinus townsendii pallescens	Pale Townsend's Big-Eared Bat	FS Sensitive
Cynomys gunnisoni	Gunnison's prairie dog	
Euderma maculatum	Spotted bat	FS Sensitive
Eumops perotis californicus	Greater Western Mastiff Bat	FS Sensitive
Idionycteris phyllotis	Allen's Lappet-Browed Bat	FS Sensitive
Lasiurus blossevillii	Western red bat	FS Sensitive
Microtus mogollonensis navajo	Navajo Mogollon Vole	FS Sensitive
Mustela nigripes	Black-footed ferret	Endangered
Myotis auriculus	Southwestern myotis	
Myotis occultus	Arizona Myotis	
Perognathus amplus cineris	Wupatki Arizona Pocket Mouse	FS Sensitive
Puma concolor	Mountain lion	
Reithrodontomys montanus	Plains harvest mouse	FS Sensitive
Sorex merriami leucogenys	Merriam's Shrew	FS Sensitive
Sorex nanus	Dwarf shrew	FS Sensitive
Plants 98		
Abies lasiocarpa var. arizonica	Corkbark (subalpine) Fir	
Actaea arizonica	Arizona Bugbane	Candidate/FS Sensitive
Agave delamateri	Tonto Basin Agave	FS Sensitive
Agave phillipsiana	Phillips' agave	FS Sensitive
Aletes macdougalii	Macdougal's Aletes	
Allium bigelovii	Bigelow's Onion	

Anulocaulis leiosolenus var. leiosolenus	Southwestern ringstem	
Aquilegia caerulea var. pinetorum	Columbine	
Arenaria aberrans	Mt. Dellenbaugh Sandwort	FS Sensitive
Arenaria fendleri var. porteri	Porter's sandwort	
Asclepias hallii	Hall's Milkweed	
Asclepias quinquedentata	Slimpod milkweed	
Asplenium adiantum-nigrum	Black spleenwort	
Asplenium platyneuron	Ebony spleenwort	
Astragalus rusbyi	Rusby's Milk-vetch	FS Sensitive
Astragalus subcinereus	Silver Milkvetch	
Astragalus troglodytus	Creeping Milk-vetch	
Botrychium crenulatum	Crenulate Moonwort	FS Sensitive
Botrychium echo	Reflected Moonwort	
Botrychium lunaria	Common moonwort	
Calystegia macounii	Macoun's false bindweed	
Camissonia gouldii	Diamond Valley Suncup	
Carex elynoides	Blackroot sedge	
Carex heteroneura	Different-nerve sedge	
Carex oreocharis	A Sedge	
Carex ultra	Cochise Sedge	FS Sensitive
Chrysothamnus molestus	Disturbed (Tusayan) rabbitbrush	FS Sensitive
Cirsium parryi ssp. mogollonicum	Mogollon Thistle	FS Sensitive
Clematis hirsutissima var. hirsutissima	Clustered Leather-flower	
Cleome lutea var. jonesii	Jones' Spider-flower	
Cymopterus megacephalus	Large leaf spring parsley	
Cystopteris utahensis	Utah Bladder Fern	
Desmodium metcalfei	Metcalfe's ticktrefoil	FS Sensitive
Draba asprella var. asprella	Rough Whitlow-grass	
Draba asprella var. stelligera	Rough Whitlow-grass	
Epilobium oregonense	Oregon willowherb	
Erigeron saxatilis	Cliff Fleabane	FS Sensitive
Eriogonum corymbosum var. glutinosum	Wild Buckwheat	
Eriogonum ericifolium var. ericifolium	Heathleaf Wild Buckwheat	FS Sensitive
Eriogonum ericifolium var. pulchrum	Yavapai wild buckwheat	
Eriogonum jonesii	Jones' Wild Buckwheat	
Eriogonum ripleyi	Ripley's Wild-buckwheat	FS Sensitive
Galium collomiae	Fossil Creek Bedstraw	
Gentianella tenella	Dane's dwarf gentian	

Gentianopsis barbellata	Bearded gentian	
Hedeoma diffusa	Flagstaff Pennyroyal	FS Sensitive
Helenium arizonicum	Arizona Sneezeweed	FS Sensitive
Helianthus arizonensis	Arizona sunflower	FS Sensitive
Heuchera eastwoodiae	Senator Mine Alum-root	FS Sensitive
Heuchera novomexicana	New Mexico Alum-root	
Hymenoxys jamesii	James' Rubberweed	
Isoetes bolanderi	Bollander's quillwort	
Ivesia arizonica var. arizonica	Arizona Whitefeather	
Lepidium montanum var. glabrum	Mountain Pepperweed	
Lesquerella cinerea	Basin Bladder-pod	
Lotus mearnsii var. mearnsii	Mearns lotus	
Macromeria viridiflora var. thurberi	Giant-trumpets	
Macromeria viridiflora var. viridiflora	Giant-trumpets	
Mertensia macdougalii	Macdougal's Bluebells	
Moneses uniflora	Wood nymph	
Myosurus nitidus	Western Mouse-tail	
Nuphar lutea	Pond lily	
Packera franciscana	San Francisco Peaks Groundsel	Threatened
Pediomelum mephiticum	Skunk-top Scurfpea	
Pellaea lyngholmii	Lyngholm's Cliffbrake	FS Sensitive
Penstemon caespitosus var. desertipicti	Mat Penstemon	
Penstemon clutei	Sunset Crater Beardtongue	FS Sensitive
Penstemon linarioides ssp. compactifolius	Toadflax Beardtongue	
Penstemon nudiflorus	Flagstaff Beardtongue	FS Sensitive
Penstemon oliganthus	Apache Beardtongue	
Perityle congesta	Compacted Rock Daisy	
Phacelia crenulata var. angustifolia	Cleftleaf Scorpionweed	
Phacelia serrata	Serrate Phacelia	
Phemeranthus validulus =Talinum validulum	Western Flame-flower	
Phlox amabilis	Arizona Phlox	
Pinus aristata	Bristlecone Pine	
Platanthera zothecina	Alcove Bog-orchid	FS Sensitive
Polemonium pulcherrimum ssp. delicatum	Beautiful Jacob's Ladder	
Polygala rusbyi	Rusby's Milkwort	FS Sensitive
Populus tremuloides	Quaking aspen	
Porterella carnosula	Western Porterella	
Potentilla crinita var. lemmonii	Bearded Cinquefoil	

Potentilla thurberi var. sanguinea	Thurber's Cinquefoil	
Purshia subintegra	Arizona Cliffrose	Endangered
Ranunculus inamoenus var. subaffinis	A Buttercup	
Ranunculus oreogenes	Oregon Buttercup	
Rumex orthoneurus	Blumer's Dock	FS Sensitive
Salix bebbiana	Bebb's willow	FS Sensitive
Salvia dorrii ssp. mearnsii	Verde Valley Sage	FS Sensitive
Saxifraga cespitosa ssp. exaratoides	Tufted Saxifrage	
Saxifraga flagellaris	Spider Saxifrage	
Sisyrinchium longipes	Timberland Blue-eye-grass	
Spiranthes romanzoffiana	Hooded lady's tresses	
Sporobolus interruptus	Black Dropseed	
Stachys rothrockii	Rothrock's Hedge-nettle	
Triteleia lemmoniae	Oak Creek Triteleia	
Utricularia vulgaris	Common bladderwort	
Xanthoparmelia huachucensis	Huachuca xanthoparmelia lichen	

APPENDIX G: HABITAT ASSOCIATIONS FOR SPECIES CARRIED FORWARD IN PLAN REVISION

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Bird	*Accipiter gentilis*	Northern goshawk										1		1				
Bird	*Aechmophorus clarkii*	Clark‘s grebe									1							
Bird	*Athene cunicularia hypugaea*	Western burrowing owl			1		1								1			
Bird	*Buteo regalis*	Ferruginous hawk			1		1								1			
Bird	*Buteogallus anthracinus*	Common black hawk	1			1												
Bird	*Catharus ustulatus*	Swainson's thrush												1		1		
Bird	*Coccothraustes vesperinus*	Evening grosbeak										1						
Bird	*Coccyzus americanus occidentalis*	Western yellow-billed cuckoo	1			1												
Bird	*Empidonax traillii extimus*	Southwestern willow flycatcher	1															
Bird	*Falco peregrinus anatum*	American peregrine falcon*																
Bird	*Gymnogyps californianus*	California condor**																
Bird	*Haliaeetus leucocephalus*	Bald eagle										1						
Bird	*Haliaeetus leucocephalus pop. 3*	Bald eagle	1															
Bird	*Oporonis tolmiei*	MacGillivray's warbler				1							1	1				
Bird	*Pipilo aberti*	Abert's Towhee	1	1				1										
Bird	*Rallus longirostris*	Yuma clapper rail	1															

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
	yumanensis																	
Bird	*Regulus satrapa*	Golden-crowned kinglet												1		1		
Bird	*Strix occidentalis lucida*	Mexican spotted owl				1						1		1				
Fish	*Agosia chrysogaster*	Longfin dace																1
Fish	*Catostomus clarki*	Desert sucker																1
Fish	*Catostomus discobolus*	Bluehead sucker																1
Fish	*Catostomus insignis*	Sonora Sucker																1
Fish	*Catostomus sp. 3*	Little Colorado Sucker																1
Fish	*Gila intermedia*	Gila Chub																1
Fish	*Gila nigra*	Headwater Chub																1
Fish	*Gila robusta*	Roundtail Chub																1
Fish	*Lepidomeda vittata*	Little Colorado Spinedace																1
Fish	*Meda fulgida*	Spikedace																1
Fish	*Oncorhynchus gilae gilae*	Gila Trout																1
Fish	*Poeciliopsis occidentalis occidentalis*	Gila topminnow																1
Fish	*Ptychocheilus lucius*	Colorado Pikeminnow																1
Fish	*Tiaroga cobitis*	Loach Minnow																1
Fish	*Xyrauchen texanus*	Razorback sucker																1
Amphib/reptile	*Bufo microscaphus*	Arizona toad	1															
Amphib/reptile	*Heloderma suspectum suspectum*	Gila monster	1	1	1	1		1										
Amphib/reptile	*Kinosternon sonoriense*	Sonora mud turtle																1
Amphib/reptile	*Lithobates chiricahuensis*	Chiricahua Leopard Frog																1
Amphib/reptile	*Lithobates pipiens*	Northern leopard frog									1							1
Amphib/reptile	*Lithobates yavapaiensis*	Lowland leopard frog																1

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Amphib/reptile	*Thamnophis eques*	Northern Mexican gartersnake	1			1												1
Amphib/reptile	*Thamnophis rufipunctatus*	Narrow-headed gartersnake																1
Invertebrate	*Acrolophitus nevadensis*	Nevada pointed-headed grasshopper										1						
Invertebrate	*Aeshna persephone*	Persephone's darner																1
Invertebrate	*Anacroneuria wipukupa*	A stonefly																1
Invertebrate	*Anodonta californiensis*	California Floater																1
Invertebrate	*Apatania arizona*	A caddisfly																1
Invertebrate	*Atopsyche sperryi*	A caddisfly																1
Invertebrate	*Atopsyche tripunctata*	A caddisfly																1
Invertebrate	*Baetodes arizonensis*	A mayfly																1
Invertebrate	*Ceratopsyche venada*	A caddisfly																1
Invertebrate	*Chimarra primula*	A caddisfly																1
Invertebrate	*Cicindela oregona Maricopa*	Maricopa tiger beetle	1															
Invertebrate	*Culoptila kimminsi*	A caddisfly																1
Invertebrate	*Culoptila moselyi*	A caddisfly																1
Invertebrate	*Ithytrichia mexicana*	A caddisfly																1
Invertebrate	*Lepidostoma knulli*	A caddisfly																1
Invertebrate	*Nectopsyche dorsalis*	A caddisfly																1
Invertebrate	*Ochrotrichia ildria*	A caddisfly																1
Invertebrate	*Oeneis alberta daura*	Alberta Arctic										1		1	1	1	1	
Invertebrate	*Ophiogomphus arizonicus*	Arizona Snaketail																1
Invertebrate	*Piruna polingii*	Four-spotted Skipperling				1					1		1		1			
Invertebrate	*Polycentropus arizonensis*	A caddisfly																1
Invertebrate	*Polycentropus gertschi*	A caddisfly																1

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Invertebrate	*Protoptila balmorhea*	Balmorhea saddle-case caddisfly																1
Invertebrate	*Pyrgulopsis morrisoni*	Page springsnail																1
Invertebrate	*Pyrgulopsis simplex*	Fossil Springsnail																1
Invertebrate	*Radiodiscus millecostatus*	Ribbed pinwheel										1		1		1		
Invertebrate	*Smicridea dispar*	A caddisfly																1
Invertebrate	*Sonorella coltoniana*	Walnut Canyon Talussnail						1										
Invertebrate	*Sonorella compar*	Oak Creek Talussnail*																
Invertebrate	*Sonorella micromphala*	Milk Ranch Talussnail*																
Invertebrate	*Speyeria nokomis nitocris*	Nitocris Fritillary				1						1		1				
Invertebrate	*Speyeria nokomis nokomis*	Nokomis Fritillary				1						1		1				
Invertebrate	*Wormaldia arizonensis*	A caddisfly																1
Mammal	*Antilocapra americana*	Pronghorn			1		1								1			
Mammal	*Canis lupus baileyi*	Mexican gray wolf**																
Mammal	*Castor canadensis*	Beaver	1			1												1
Mammal	*Corynorhinus townsendii pallescens*	Pale Townsend's Big-Eared Bat*																
Mammal	*Cynomys gunnisoni*	Gunnison's prairie dog			1		1								1			
Mammal	*Euderma maculatum*	Spotted bat*																
Mammal	*Eumops perotis californicus*	Greater Western Mastiff Bat *																
Mammal	*Idionycteris phyllotis*	Allen's Lappet-Browed Bat										1		1				
Mammal	*Lasiurus blossevillii*	Western red bat	1			1												
Mammal	*Microtus mogollonensis navaho*	Navajo Mogollon Vole								1		1		1		1		
Mammal	*Mustela nigripes*	Black-footed ferret					1								1			
Mammal	*Myotis auriculus*	Southwestern myotis										1						
Mammal	*Myotis occultus*	Arizona Myotis	1			1						1						

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Mammal	*Perognathus amplus cineris*	Wupatki Arizona Pocket Mouse					1											
Mammal	*Puma concolor*	Mountain lion**																
Mammal	*Reithrodontomys montanus*	Plains harvest mouse			1													
Mammal	*Sorex merriami leucogenys*	Merriam's Shrew								1		1		1	1	1		
Mammal	*Sorex nanus*	Dwarf shrew													1	1	1	
Plant	*Abies lasiocarpa var. arizonica*	Corkbark (subalpine) Fir														1		
Plant	*Actaea arizonica*	Arizona Bugbane				1												
Plant	*Agave delamateri*	Tonto Basin Agave			1				1									
Plant	*Agave phillipsiana*	Phillips' agave			1				1									
Plant	*Aletes macdougalii*	Macdougal's Aletes				1												
Plant	*Allium bigelovii*	Bigelow's Onion		1	1													
Plant	*Anulocaulis leiosolenus var. leiosolenus*	Southwestern ringstem		1														
Plant	*Aquilegia caerulea var. pinetorum*	Columbine												1		1		
Plant	*Arenaria aberrans*	Mt. Dellenbaugh Sandwort													1			
Plant	*Arenaria fendleri var. porteri*	Porter's sandwort															1	
Plant	*Asclepias hallii*	Hall's Milkweed								1		1						
Plant	*Asclepias quinquedentata*	Slimpod milkweed										1						
Plant	*Asplenium adiantum-nigrum*	Black spleenwort**																
Plant	*Asplenium platyneuron*	Ebony spleenwort										1		1				
Plant	*Astragalus rusbyi*	Rusby's Milk-vetch										1		1				
Plant	*Astragalus subcinereus*	Silver Milkvetch							1	1		1						
Plant	*Astragalus troglodytus*	Creeping Milk-vetch							1	1		1						

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Plant	*Botrychium crenulatum*	Crenulate Moonwort														1	1	
Plant	*Botrychium echo*	Reflected Moonwort													1	1		
Plant	*Botrychium lunaria*	Common moonwort												1	1		1	
Plant	*Calystegia macounii*	Macoun's false bindweed										1			1			
Plant	*Camissonia gouldii*	Diamond Valley Suncup								1								
Plant	*Carex elynoides*	Blackroot sedge															1	
Plant	*Carex heteroneura*	Different-nerve sedge															1	
Plant	*Carex oreocharis*	A Sedge													1			
Plant	*Carex ultra*	Cochise Sedge	1															
Plant	*Chrysothamnus molestus*	Disturbed (Tusayan) rabbitbrush					1			1								
Plant	*Cirsium parryi ssp. mogollonicum*	Mogollon Thistle											1					
Plant	*Clematis hirsutissima var. hirsutissima*	Clustered leather-flower										1						
Plant	*Cleome lutea var. jonesii*	Jones' spider-flower	1							1								
Plant	*Cymopterus megacephalus*	Large -leaf Spring Parsley		1					1									
Plant	*Cystopteris utahensis*	Utah Bladder Fern								1		1						
Plant	*Desmodium metcalfei*	Metcalfe's ticktrefoil			1				1									
Plant	*Draba asprella var. asprella*	Rough Whitlow-grass										1						
Plant	*Draba asprella var. stelligera*	Rough Whitlow-grass										1						
Plant	*Epilobium oregonense*	Oregon willowherb									1		1	1				
Plant	*Erigeron saxatilis*	Cliff Fleabane				1						1						
Plant	*Eriogonum corymbosum var. glutinosum*	Wild Buckwheat							1	1								
Plant	*Eriogonum ericifolium var. ericifolium*	Heathleaf Wild Buckwheat		1	1				1									

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Plant	*Eriogonum ericifolium var. pulchrum*	Yavapai wild buckwheat								1		1						
Plant	*Eriogonum jonesii*	Jones' Wild Buckwheat								1								
Plant	*Eriogonum ripleyi*	Ripley's Wild-buckwheat		1	1				1									
Plant	*Galium collomiae*	Fossil Creek Bedstraw							1									
Plant	*Gentianella tenella*	Dane's dwarf gentian															1	
Plant	*Gentianopsis barbellata*	Bearded gentian															1	
Plant	*Hedeoma diffusa*	Flagstaff Pennyroyal										1						
Plant	*Helenium arizonicum*	Arizona Sneezeweed										1			1			
Plant	*Helianthus arizonensis*	Arizona sunflower								1								
Plant	*Heuchera eastwoodiae*	Senator Mine Alum-root				1				1		1						
Plant	*Heuchera novomexicana*	New Mexico Alum-root				1			1									
Plant	*Hymenoxys jamesii*	James' Rubberweed								1		1						
Plant	*Isoetes bolanderi*	Bollander's quillwort									1							1
Plant	*Ivesia arizonica var. arizonica*	Arizona Whitefeather				1			1			1						
Plant	*Lepidium montanum var. glabrum*	Mountain Pepperweed		1					1									
Plant	*Lesquerella cinerea*	Basin Bladder-pod		1					1									
Plant	*Lotus mearnsii var. mearnsii*	Mearns lotus		1	1													
Plant	*Macromeria viridiflora var. thurberi*	Giant-trumpets										1						
Plant	*Macromeria viridiflora var. viridiflora*	Giant-trumpets										1						
Plant	*Mertensia macdougalii*	Macdougal's Bluebells										1	1					
Plant	*Moneses uniflora*	Wood nymph										1		1		1		
Plant	*Myosurus nitidus*	Western Mouse-tail										1						

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Plant	*Nuphar lutea*	Pond lily									1							1
Plant	*Packera franciscana*	San Francisco Peaks Groundsel															1	
Plant	*Pediomelum mephiticum*	Skunk-top Scurfpea		1	1				1									
Plant	*Pellaea lyngholmii*	Lyngholm's Cliffbrake							1				1	1				
Plant	*Penstemon caespitosus var. desertipicti*	Mat penstemon								1								
Plant	*Penstemon clutei*	Sunset Crater Beardtongue								1		1						
Plant	*Penstemon linarioides ssp. compactifolius*	Toadflax Beardtongue								1		1						
Plant	*Penstemon nudiflorus*	Flagstaff Beardtongue								1		1						
Plant	*Penstemon oliganthus*	Apache Beardtongue										1			1			
Plant	*Perityle congesta*	Compacted Rock Daisy							1			1						
Plant	*Phacelia crenulata var. angustifolia*	Cleflleaf Scorpionweed					1			1								
Plant	*Phacelia serrata*	Serrate Phacelia								1		1						
Plant	*Phemeranthus validulus*	Western Flame-flower								1		1						
Plant	*Phlox amabilis*	Arizona Phlox							1	1		1						
Plant	*Pinus aristata*	Bristlecone Pine														1	1	
Plant	*Platanthera zothecina*	Alcove Bog-orchid				1												
Plant	*Polemonium pulcherrimum ssp. delicatum*	Beautiful Jacob's Ladder												1		1		
Plant	*Polygala rusbyi*	Rusby's Milkwort		1	1				1									
Plant	*Populus tremuloides*	Quaking aspen												1				
Plant	*Porterella carnosula*	Western Porterella									1							
Plant	*Potentilla crinita var. lemmonii*	Bearded Cinquefoil										1						
Plant	*Potentilla thurberi var. sanguinea*	Thurber's Cinquefoil				1						1						

Taxa	*Scientific-Name*	Common-Name	Cottonwood Willow Riparian	Desert Communities	Semi-desert Grassland	Mixed Broad Leaf Deciduous Riparian	Great Basin Grassland	Interior Chaparral	Pinyon Juniper Evergreen Shrub	Pinyon Juniper Woodland	Wetland Cienega	Ponderosa Pine	Montane Willow Riparian Forest	Dry Mixed Conifer	Montane Subalpine Grassland	Spruce Fir Forest	Alpine Tundra	Water
Plant	*Purshia subintegra*	Arizona Cliffrose		1														
Plant	*Ranunculus inamoenus var. subaffinis*	A Buttercup														1	1	
Plant	*Ranunculus oreogenes*	Oregon Buttercup										1						
Plant	*Rumex orthoneurus*	Blumer's Dock											1					
Plant	*Salix bebbiana*	Bebb's willow											1					
Plant	*Salvia dorrii ssp. mearnsii*	Verde Valley Sage		1	1				1									
Plant	*Saxifraga caespitosa ssp. exaratoides*	Tufted Saxifrage															1	
Plant	*Saxifraga flagellaris*	Spider Saxifrage														1	1	
Plant	*Sisyrinchium longipes*	Timberland Blue-eye-grass											1	1		1		
Plant	*Spiranthes romanzoffiana*	Hooded lady's tresses										1						
Plant	*Sporobolus interruptus*	Black Dropseed										1			1			
Plant	*Stachys rothrockii*	Rothrock's Hedge-nettle							1	1		1						
Plant	*Triteleia lemmoniae*	Oak Creek Triteleia										1						
Plant	*Utricularia vulgaris*	Common bladderwort									1	1						
Plant	*Xanthoparmelia huachucensis*	Huachuca Xanthoparmelia lichen										1						
* Species associated with cliffs, caves or talus slopes. **Species not associated with specific PNVT or ecosystem diversity characteristic. Analysis is separate.																		

APPENDIX H: SPECIES CONSIDERED TO BE NONNATIVE, INVASIVE, OR THREATS

Species identified as nonnative or invasive or considered as threats to species or ecosystems and known from the Forest are listed below. Nonnative fish species are listed in Table H-1.

Brown-headed cowbird (*Molothrus ater)*: This common brood parasite is considered widespread throughout AZ; found in almost all potential vegetation communities including agricultural and residential areas, and breeds across a wide elevation range. This species was confined to the Great Plains region of North America prior to European settlement. They now breed from southeastern Alaska south and east through much of the US, northern Baja California and northern and central Mexico. A common summer resident in AZ that breeds from 90-9300 feet elevation. Breeding Bird surveys documented species throughout AZ and the data shows regional variation in population trends with an overall significant decline in AZ. Species is considered as a threat to native birds. Secure in AZ according to NatureServe (2007). Common summer and winter resident in Verde Valley environs according to Northern AZ Audubon lists (2006).

Eurasian collared dove (*Streptopelia decaocto*): This introduced species is rapidly expanding in AZ and is not ranked in NatureServe. Mainly associated with suburban and rural communities. Unknown effects on Arizona's indigenous birds (Corman and Gervais-Wise 2005).

European starling (*Sturnus vulgaris*): An introduced species associated with human populations across AZ and a wide variety of vegetative communities. Increasing population trend. Aggressively displaces cavity nesting birds.

Bullfrog *(Rana catesbeiana):* This widespread exotic is not ranked in NatureServe. Occurs on Forest. Is predator to native species including fish and amphibians.

Pond (red) slider (*Trachemys scripta):* This exotic not ranked in AZ by Natureserve. Eats aquatic animals and is threat to native species, such as the Sonoran mud turtle.

Northern crayfish (*Orconectes virilis*): Native to north-central and northeastern US and Canada. Not native to AZ. Broadly distributed in streams, rivers and lakes of east-central and southeastern Arizona. Of management concern because is destructive to native flora and fauna.

Spruce aphid (*Elatobium abietinum*): This exotic is not listed in Natureserve. It established on the San Francisco Peaks in 1999 and has persisted in the spruce component of Dry Mixed Conifer and spruce fir since then. There is a concern that its persistence may lead to a general decline of Engelmann spruce as has been seen in the White Mountains of Arizona.

Table H-1: Occurrence (X) of nonnative fish species by 4th and 5th code watershed

Common Name	Scientific Name	Upper Verde River					Lower Verde River		Middle Little Colorado R.
		Sycamore Creek	Oak Creek	Beaver Creek	Cherry Crk-Upper Verde	Grindstone Wash-Upper Verde River	West Clear Creek	Fossil Creek-Lower Verde River	Upper Clear Creek
Fathead minnow	*Pimephales promelas*		X	X	X	X	X	X	X
Green sunfish	*Lepomis cyanellus*	X	X	X	X	X	X	X	X
Golden shiner	*Notemigonus crysoleucas*								X
Red shiner	*Notropis lutrensis*	X	X	X	X	X	X	X	
Western mosquitofish	*Gambusia affinis*	X	X	X	X	X	X	X	
Bluegill	*Lepomis macrochirus*		X	X	X	X	X	X	
Black crappie	*Pomoxis nigromaculatus*								X
Largemouth bass	*Micropterus salmoides*		X	X	X	X	X	X	
Smallmouth bass	*Micropterus dolomieu*	X	X	X	X	X	X	X	
Northern pike	*Esox lucius*								X
Walleye	*Stizostedion vitreum*								X
Yellow perch	*Perca flavescens*								X
Arctic grayling	*Thymallus arcticus*								X
Brook trout	*Salvelinus fontinalis*								X
Brown trout	*Salmo trutta*		X	X	X	X	X	X	X
Cutthroat trout	*Oncorhynchus clarki*								X
Rainbow trout	*Oncorhynchus mykiss*		X	X	X	X	X	X	X
Channel catfish	*Ictalurus punctatus*		X	X	X	X	X	X	
Flathead catfish	*Pylodictis olivaris*		X	X	X	X	X	X	
Yellow bullhead	*Ictalurus natalis*	X	X	X	X	X	X	X	
Carp	*Cyprinus carpio*		X	X	X	X	X	X	

APPENDIX I: THREATS

Threats to ecosystem and aquatic systems are categorized below as to whether they are under the control and authority of the Forest Service. Agency control means the Forest Service can make the decision. Agency authority means the Forest Service can regulate or mitigate.

Threat	Forest Service control	Forest Service authority
Unmanaged grazing by cattle	YES	YES
Managed grazing	YES	YES
Unmanaged grazing by wildlife	NO	YES
Fire Management (prescribed, wildland fire use)	YES	YES
Fire exclusion	YES	YES
Fire suppression	YES	YES
Wildfire	NO	YES
Vegetation treatments (including fuelwood)	YES	YES
Insect, disease, pathogens and parasites	NO	YES
Drought	NO	YES
Flooding	NO	YES
Invasive plants	YES	YES
Invasive animals	YES	YES
Leasable Minerals (Gypsum)	NO	YES
Minerals	YES	YES
Roads and Motorized Trails (footprint and infrastructure)	YES	YES
Non motorized trails (footprint)	YES	YES
Roads and Motorized Trails Use	YES	YES
Cross Country Vehicle Use	YES	YES
Social trails (Non motorized trail use)	YES	YES
Dispersed recreation (Non motorized off trail use)	YES	YES
Developed recreation	YES	YES
Dams and impoundments	YES	YES
Water withdrawal, well pumping	NO	NO
Water diversion	NO	NO
Pesticides (FS use)	YES	NO
Power lines, Utility Corridors, Electronic Sites, and Cell Towers, Wind farms	YES	YES
Firewood (illegal cutting)	YES	YES
Sewage, septic	YES	YES
Solid waste dumping	YES	YES

Appendix J: Endemic and Limited Distribution Species.

Taxa	Scientific Name	Common Name	
Bird	*Gymnogyps californianus*	California condor	Limited distribution
Bird	*Haliaeetus leucocephalus pop. 3*	Bald eagle	Limited distribution
Bird	*Pipilo aberti*	Abert's Towhee	Limited distribution
Bird	*Rallus longirostris yumanensis*	Yuma clapper rail	Limited distribution
Bird	*Strix occidentalis lucida*	Mexican spotted owl	Limited distribution
Fish	*Catostomus clarki*	Desert sucker	Limited distribution
Fish	*Catostomus insignis*	Sonora Sucker	Limited distribution
Fish	*Gila intermedia*	Gila Chub	Limited distribution
Fish	*Gila nigra*	Headwater Chub	Limited distribution
Fish	*Lepidomeda vittata*	Little Colorado Spinedace	Endemic
Fish	*Meda fulgida*	Spikedace	Limited distribution
Fish	*Oncorhynchus gilae gilae*	Gila Trout	Limited distribution
Fish	*Poeciliopsis occidentalis occidentalis*	Gila topminnow	Limited distribution
Fish	*Tiaroga cobitis*	Loach Minnow	Limited distribution
Fish	*Xyrauchen texanus*	Razorback sucker	Limited distribution
Fish	*Bufo microscaphus*	Arizona toad	Limited distribution
Fish	*Lithobates yavapaiensis*	Lowland leopard frog	Limited distribution
Fish	*Lithobates chiricahuensis*	Chiricahua Leopard Frog	Limited distribution
Fish	*Thamnophis eques*	Northern Mexican gartersnake	Limited distribution
Fish	*Thamnophis rufipunctatus*	Narrow-headed gartersnake	Limited distribution
Invertebrate	*Anacroneuria wipukupa*	A stonefly	Limited distribution
Invertebrate	*Apatania arizona*	A caddisfly	Limited distribution
Invertebrate	*Atopsyche sperryi*	A caddisfly	Limited distribution
Invertebrate	*Atopsyche tripunctata*	A caddisfly	Limited distribution
Invertebrate	*Baetodes arizonensis*	A mayfly	Limited distribution
Invertebrate	*Chimarra primula*	A caddisfly	Limited distribution
Invertebrate	*Culoptila kimminsi*	A caddisfly	Limited distribution
Invertebrate	*Culoptila moselyi*	A caddisfly	Limited distribution
Invertebrate	*Ithytrichia mexicana*	A caddisfly	Limited distribution
Invertebrate	*Lepidostoma knulli*	A caddisfly	Limited distribution
Invertebrate	*Nectopsyche dorsalis*	A caddisfly	Limited distribution
Invertebrate	*Ochrotrichia ildria*	A caddisfly	Limited distribution
Invertebrate	*Ophiogomphus arizonicus*	Arizona Snaketail	Limited distribution
Invertebrate	*Polycentropus arizonensis*	A caddisfly	Limited distribution
Invertebrate	*Polycentropus gertschi*	A caddisfly	Limited distribution
Invertebrate	*Protoptila balmorhea*	Balmorhea saddle-case caddisfly	Limited distribution
Invertebrate	*Pyrgulopsis morrisoni*	Page springsnail	Endemic
Invertebrate	*Pyrgulopsis simplex*	Fossil Springsnail	Endemic
Invertebrate	*Sonorella coltoniana*	Walnut Canyon Talussnail	Endemic
Invertebrate	*Sonorella compar*	Oak Creek Talussnail	Endemic
Invertebrate	*Sonorella micromphala*	Milk Ranch Talussnail	Endemic
Invertebrate	*Speyeria nokomis nokomis*	Nokomis Fritillary	Limited distribution
Mammal	*Canis lupus baileyi*	Mexican Gray Wolf	Limited distribution
Mammal	*Myotis auriculus*	Southwestern myotis	Limited distribution
Mammal	*Perognathus amplus cineris*	Wupatki Arizona Pocket Mouse	Endemic
Plant	*Actaea arizonica*	Arizona Bugbane	Endemic

Taxa	Scientific Name	Common Name	
Plant	*Agave delamateri*	Tonto Basin Agave	Limited distribution
Plant	*Agave phillipsiana*	Phillips' agave	Limited distribution
Plant	*Aletes macdougalii*	Macdougal's Aletes	Limited distribution
Plant	*Aquilegia caerulea var. pinetorum*	Columbine	Limited distribution
Plant	*Arenaria aberrans*	Mt. Dellenbaugh Sandwort	Endemic
Plant	*Arenaria fendleri var. porteri*	Porter's sandwort	Limited distribution
Plant	*Astragalus rusbyi*	Rusby's Milk-vetch	Endemic
Plant	*Astragalus subcinereus*	Silver Milkvetch	Limited distribution
Plant	*Astragalus troglodytus*	Creeping Milk-vetch	Limited distribution
Plant	*Camissonia gouldii*	Diamond Valley Suncup	Limited distribution
Plant	*Carex ultra*	Cochise Sedge	Limited distribution
Plant	*Chrysothamnus molestus*	Disturbed (Tusayan) rabbitbrush	Endemic
Plant	*Cirsium parryi ssp. mogollonicum*	Mogollon Thistle	Endemic
Plant	*Cleome lutea var. jonesii*	Jones' spider-flower	Limited distribution
Plant	*Cymopterus megacephalus*	Large -leaf Spring Parsley	Endemic
Plant	*Desmodium metcalfei*	Metcalfe's ticktrefoil	Limited distribution
Plant	*Draba asprella var. asprella*	Rough Whitlow-grass	Endemic
Plant	*Draba asprella var. stelligera*	Rough Whitlow-grass	Endemic
Plant	*Erigeron saxatilis*	Cliff Fleabane	Endemic
Plant	*Eriogonum ericifolium var. ericifolium*	Heathleaf Wild Buckwheat	Endemic
Plant	*Eriogonum ericifolium var. pulchrum*	Yavapai wild buckwheat	Endemic
Plant	*Eriogonum jonesii*	Jones' Wild Buckwheat	Endemic
Plant	*Eriogonum ripleyi*	Ripley's Wild-buckwheat	Endemic
Plant	*Galium collomiae*	Fossil Creek Bedstraw	Endemic
Plant	*Hedeoma diffusa*	Flagstaff Pennyroyal	Endemic
Plant	*Helenium arizonicum*	Arizona Sneezeweed	Endemic
Plant	*Helianthus arizonensis*	Arizona sunflower	Limited distribution
Plant	*Heuchera eastwoodiae*	Senator Mine Alum-root	Endemic
Plant	*Heuchera novomexicana*	New Mexico Alum-root	Limited distribution
Plant	*Hymenoxys jamesii*	James' Rubberweed	Endemic
Plant	*Lepidium montanum var. glabrum*	Mountain Pepperweed	Endemic
Plant	*Lesquerella cinerea*	Basin Bladder-pod	Endemic
Plant	*Lotus mearnsii var. mearnsii*	Mearns lotus	Endemic
Plant	*Mertensia macdougalii*	Macdougal's Bluebells	Limited distribution
Plant	*Myosurus nitidus*	Western Mouse-tail	Limited distribution
Plant	*Packera franciscana*	San Francisco Peaks Groundsel	Endemic
Plant	*Pediomelum mephiticum*	Skunk-top Scurfpea	Limited distribution
Plant	*Pellaea lyngholmii*	Lyngholm's Cliffbrake	Endemic
Plant	*Penstemon caespitosus var. desertipicti*	Mat penstemon	Limited distribution
Plant	*Penstemon clutei*	Sunset Crater Beardtongue	Endemic
Plant	*Penstemon linarioides ssp. compactifolius*	Toadflax Beardtongue	Limited distribution
Plant	*Penstemon nudiflorus*	Flagstaff Beardtongue	Endemic
Plant	*Penstemon oliganthus*	Apache Beardtongue	Limited distribution
Plant	*Perityle congesta*	Compacted Rock Daisy	Endemic
Plant	*Phacelia crenulata var. angustifolia*	Clefflleaf Scorpionweed	Limited distribution
Plant	*Phacelia serrata*	Serrate Phacelia	Endemic
	Phemeranthus validulus	Western Flame-flower	Limited distribution

Taxa	Scientific Name	Common Name	
Plant	*Phlox amabilis*	Arizona Phlox	Endemic
Plant	*Platanthera zothecina*	Alcove Bog-orchid	Endemic
Plant	*Polygala rusbyi*	Rusby's Milkwort	Endemic
Plant	*Potentilla crinita var. lemmonii*	Bearded Cinquefoil	Endemic
Plant	*Potentilla thurberi var. sanguinea*	Thurber's Cinquefoil	Endemic
Plant	*Purshia subintegra*	Arizona Cliffrose	Endemic
Plant	*Ranunculus inamoenus var. subaffinis*	A Buttercup	Endemic
Plant	*Ranunculus oreogenes*	Oregon Buttercup	Endemic
Plant	*Rumex orthoneurus*	Blumer's Dock	Endemic
Plant	*Salvia dorrii ssp. mearnsii*	Verde Valley Sage	Endemic
Plant	*Sporobolus interruptus*	Black Dropseed	Endemic
Plant	*Triteleia lemmoniae*	Oak Creek Triteleia	Endemic