United States Department of Agriculture

Final Assessment Report of Ecological Conditions, Trends, and Risks to Sustainability

Volume I

Tonto National Forest, Arizona

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Cover Photo: The Mogollon Rim

Final Assessment Report, Volume I

Tonto National Forest

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Abstract: The Assessment Report presents and evaluates existing information about relevant ecological, economic, and social conditions, trends, and risks to sustainability and their relationship to the 1985 Tonto National Forest Land and Resource Management Plan (the forest plan), within the context of the broader landscape.

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A special thanks to all who have supported the plan revision efforts and those who plan to do so moving forward.

Contents

Tables

Figures

Photos

Chapter 1. Introduction

Purpose

The Tonto National Forest is a unit of the United States Forest Service, a land management agency in the U.S. Department of Agriculture (USDA). The mission of the Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

The principal document that guides management on the Tonto National Forest is the “Land and Resource Management Plan for the Tonto National Forest” (Tonto National Forest Plan). The Tonto National Forest Plan was originally approved in 1985 and has since been amended 28 times to accommodate situations in specific projects or to reflect changes in social, economic, or ecological conditions.

The Tonto National Forest is revising the 1985 plan using the provisions of the 2012 planning rule as outlined in 36 Code of Federal Regulations (CFR) Part 219, April 2012. This rule provides the process and structure to create local land and resource management plans for national forests across the nation. The rule establishes an ongoing, three-phase process: (1) assessment, (2) plan development or revision, and (3) monitoring.

The 2012 Planning Rule is intended to create plans that guide integrated resource management in the plan area within the context of the broader landscape. It takes an integrated approach that recognizes the interdependence between ecological processes and social and economic systems. Collaboration with stakeholders, transparency of processes, and the incorporation of best available science are key aspects of the plan revision effort.

This document represents the assessment phase of the process and is designed to evaluate readily available existing information about relevant ecological, economic, and social conditions, trends, and sustainability and their relationship to the current forest plan within the context of the broader landscape. The assessment uses information currently available and can be utilized without further data collection, modification, or validation. The assessment report is not a decision-making document, but it provides current information on planning topics (36 CFR 219.19).

During the assessment, conditions and trends of 15 assessment topics listed in 36 CFR 219.6(b) and the sustainability of social, economic, and ecological systems (36 CFR 219.5(a)(1)) are identified and evaluated. The 15 topic areas are broken into two sections. The first volume is ecologically based with topics such as terrestrial ecosystems; aquatic ecosystems and watersheds; air, soil, and water resources; system drivers; stressors including risks related to climate change; baseline assessment of carbon stocks; and threatened, endangered, proposed, candidate species and potential species of conservation concern. The second volume focuses on social and economic sustainability and multiple uses with topics such as social, cultural, and economic conditions; benefits people obtain from the Tonto (ecosystem services); multiple uses and their economic contributions; recreation settings, opportunities, and access; energy and mineral resources; infrastructure, transportation, and utility corridors; areas of tribal importance; cultural and historic resources and uses; land ownership, use, and access patterns; wilderness areas, wild and scenic rivers, and the need for additional designated areas..

Structure of the Assessment Report

Volume I of the Tonto National Forest Assessment Report includes the setting, distinctive features, and background of the plan area to describe the physical and climate characteristics and setting of the Tonto National Forest assessment area and its place with the context area. An explanation of best available scientific information follows the "Setting, Distinctive Features, and Background" section. The "Public Participation" section describes the ways the Tonto National Forest staff has interacted with the public and tribes during the early stages of the forest plan revision process.

The "Ecological Integrity and Sustainability" section of Volume I examines the conditions, trends, and risks to integrity and sustainability for the ecologically based resource areas described in the 2012 Planning Rule (36 CFR 219.6 (b)). In this part, an ecological assessment of the vegetation, soils, water, riparian, air, carbon, climate change, federally recognized species, and other species of conservation concern is conducted to understand current conditions and trends and identify key characteristics at risk for a loss of ecological integrity.

Volume II, Social and Economic Sustainability and Multiple Uses assesses the conditions, trends, and risks to sustainability for the social and economic based topic areas listed in the 2012 Planning Rule (36 CFR 219.6 (b)). It describes the contributions (goods and services) in the planning area that provide social, economic, and cultural benefits to people and communities. This assessment considers current condition of the goods and services, the stressors that affect demand or availability, their context of within the ecosystem, and their relationship to outside social, cultural, and economic conditions. This part of the assessment concludes with the issues of concern and risks to sustainability of the goods and services analyzed.

Together, volume I and volume II describe the nature, extent, and role of current ecological, economic, and social conditions and trends in both the planning area and the broader landscape. The ecological integrity and sustainability of ecosystems are intricately connected and interdependent with their ability to contribute to social and economic conditions.

Finally, volume III is the combined references list which will conclude the report.

Setting, Distinctive Features, and Background

The Tonto National Forest is the fifth largest forest in the United States, covering approximately 2,964,308 acres of rugged and spectacularly beautiful country. It is located in central Arizona, with Phoenix to the south, the Mogollon Rim to the north, and the San Carlos and Fort Apache Indian Reservations to the east. The diversity of vegetation, from Saguaro-cactus-studded deserts to pine-forested mountains, reflects the change in altitude across the Tonto National Forest from 1,300 up to 7,900 feet. This allows for outstanding recreational opportunities throughout the year, whether on lake beaches or in the cool pine forests.

The Tonto National Forest is one of the most-visited "urban" forests in the United States, with approximately 5.8 million visitors enjoying the array of year-round recreation opportunities. In the winter, national and international visitors flock to Arizona to share the multi-hued stone canyons and Sonoran desert environments of the Tonto's lower elevations with Arizona residents. In the summer, visitors and residents seek refuge from the heat at the Salt and Verde Rivers and their chain of six man-made lakes. Visitors also head to the high county to camp amidst the cool shade of tall pines and fish the meandering trout streams under the Mogollon Rim.

One of the primary purposes for establishing the Tonto National Forest in 1905 was to protect its watersheds around reservoirs. The Tonto produces an average of 350,000 acre-feet of water each year. Six major reservoirs on the Tonto have the combined capacity to store more than 2 million acre-feet of water. Management efforts are directed at protecting both water quality and watershed and riparian area conditions.

Eight wilderness areas, encompassing more than 589,300 acres, are managed to protect the unique natural character of the land and to ensure that primitive recreational opportunities exists for the public. In addition, portions of the Verde River and Fossil Creek have been designated by Congress as wild and scenic rivers.

Fish and wildlife are abundant on the Tonto; more than 400 vertebrate species are represented. The Tonto National Forest also has 22 Federal and State threatened, endangered, proposed, and candidate species. In addition to this list, we also maintain a conservation agreement for one plant species on the Tonto. Maintaining quality habitat to support and improve wildlife diversity is a primary management consideration.

Approximately 26,000 head of cattle are permitted to graze on the Tonto National Forest. Because of its year-round availability, permitted use is extremely high, and land allotments must be carefully managed to avoid over-utilization and declining productivity of the range. Currently, long-term drought conditions across the Southwest have limited our ability to sustain more than 20 percent of the permitted numbers on the Tonto.

The Tonto has a rich history of producing copper, gold, silver, lead, zinc, uranium, molybdenum, manganese, asbestos, mercury, and many other metals and minerals. This history spans over 150 years and includes 38 mineral districts with recorded production.

Although the Tonto is not heavily timbered, about 4 million board feet total of saw logs, fuel wood, and other forest wood products are selectively harvested each year.

The critical fire season is relatively short, usually lasting from May to mid July. During that period, natural and human-caused fires often threaten the timber, chaparral, grass, and light shrub vegetative zones. The Tonto has averaged 330 wildfires a year over the last ten years.

With some of the state’s more prominent peaks located on the Tonto, the national forest supports an important communication link for Arizona. Radio, television, and telephone networks use the electronic sites on these mountains to facilitate state and national communications. Many of the high-capacity transmission lines that bring Phoenix its power also crisscross the Tonto.

The Tonto National Forest overlaps five counties: 23 percent of Maricopa County, 59 percent of Gila County, 11 percent of Yavapai County, 7 percent of Pinal County, and 0.01 percent of Coconino County. The Tonto abuts the Prescott National Forest to the northwest, the Coconino National Forest to the north, and Apache Sitgreaves National Forest to the northeast (figure 1). It is divided into six ranger districts: Cave Creek, Globe, Mesa, Payson, Pleasant Valley, and Tonto Basin.

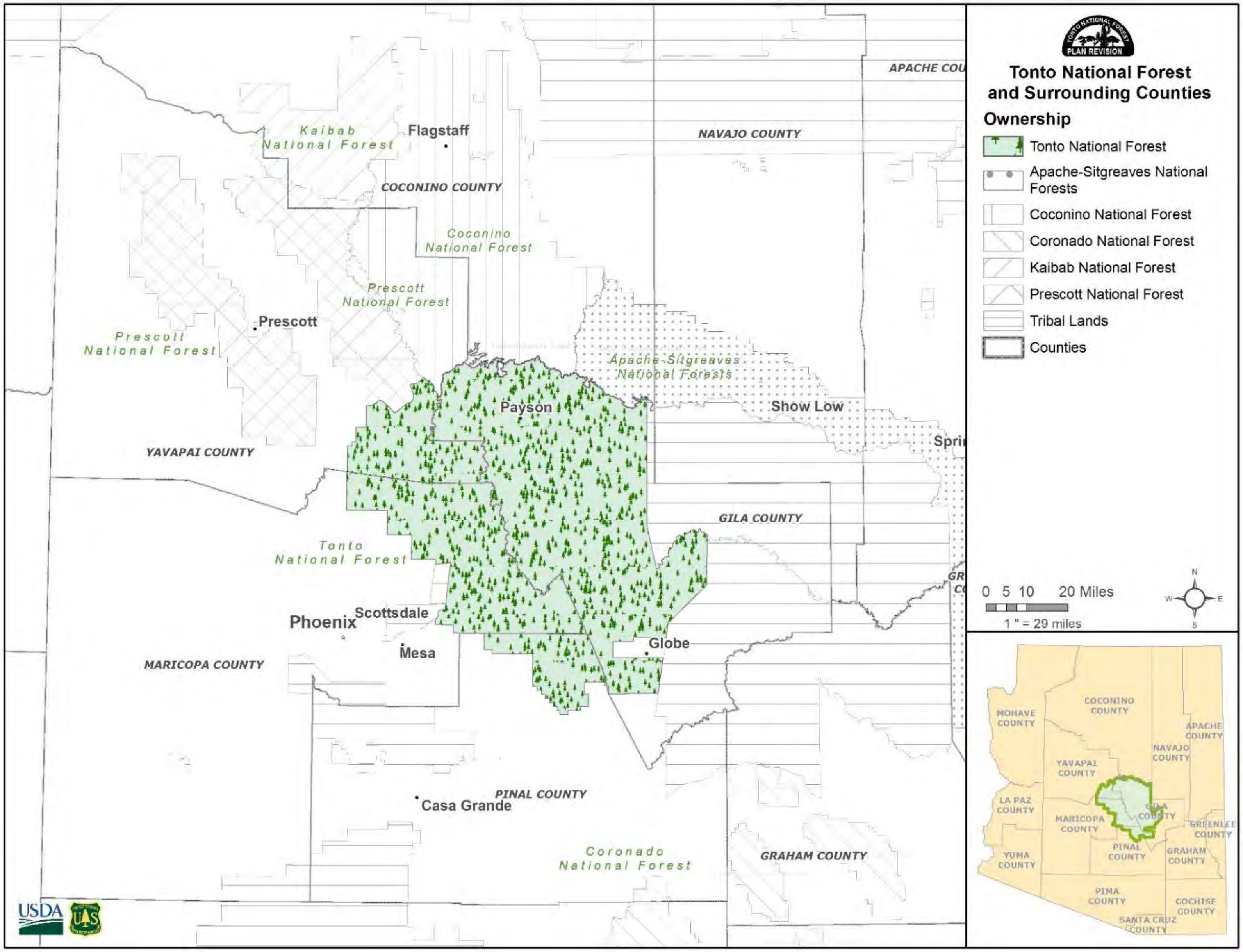


Figure 1. Vicinity map for the Tonto National Forest plan assessment

The predominant vegetation types on the Tonto National Forest are Mohave-Sonoran desert scrub with 28 percent, juniper grass with 15 percent, and pinyon-juniper evergreen shrub with 14 percent. The remainder of the Tonto is composed primarily of semi-desert grassland and interior chaparral, totaling around 23 percent. The main vegetation system drivers on the Tonto are fire disturbances, regional climate change, insects, and natural vegetation succession. More details on vegetation and drivers and stressors are provided in the "Ecological Integrity and Sustainability" section of this report.

Best Available Scientific Information

The best available scientific information is used to inform the planning process (36 CFR 219.3). This includes relevant ecological, social, and economic scientific information. While the best available scientific information informs the planning process, it does not dictate what decisions must be made. There may be competing scientific perspectives and uncertainty in the available science, and plan decisions have to also consider other relevant factors such as budget, legal authorities, traditional ecological knowledge, agency policies, and public input.

Public feedback regarding the accuracy, reliability, and relevance of scientific information helps ensure the use and documentation of the best available scientific information. The best available scientific information is cited throughout the assessment report. A list of references is found in volume III.

In developing this assessment, best available scientific information was used to evaluate conditions, trends, and risks to sustainability for the social, economic, or ecological systems found on the Tonto. We used the most accurate and reliable information available. Although the best available scientific information is commonly available in the form of peer-reviewed literature, other forms include gray literature, expert opinion, federal agency inventory and monitoring data, and specialist observations, as long as the responsible official has a reasonable basis for relying on that scientific information as the best available. Gray literature is scientific or technical information not available through usual bibliographic sources; it is typically created by government agencies, universities, corporations, research centers, associations and societies, and professional organizations. The following six factors were considered when identifying the best available scientific information:

1. The science uses well-developed scientific methods that are clearly described.
2. Logical conclusions and reasonable inferences were drawn.
3. The information has been appropriately peer reviewed.
4. A quantitative analysis was performed using appropriate statistical or quantitative methods.
5. The information is placed in proper context including spatial and temporal scales.
6. References are appropriately cited.

In the context of the best available scientific information, "available" means the information is currently available in a form useful for the planning process without further data collection, modification, or validation. Analysis or interpretation of the best available scientific information may be needed to place it in the appropriate context for planning but because limited time is allotted to complete the assessment, best available scientific information must be readily available. Public and stakeholder feedback regarding the accuracy, reliability, and relevance of scientific information can help ensure the use and documentation of the best available scientific information. The best available scientific information is cited throughout the assessment document. References included in volume III of the assessment reflect the most relevant documents, given the scope and scale of the assessment and they are determined to be the best available scientific information.

Some uncertainty exists, especially in situations relevant to global climate change; that uncertainty has been appropriately documented in the assessment. Throughout the assessment, when assumptions are made, they are stated as such. The scientific knowledge base is dynamic and ever expanding, and significant findings may be updated in the final assessment to reflect evolving scientific information. While the best available scientific information informs the planning process, plan components, and other plan content, it does not dictate what the decisions must be. First, there may be competing scientific perspectives and uncertainty in the available science. In addition, decisions may consider other relevant factors such as budget, legal authorities, traditional ecological knowledge, agency policies, public input, and the experience of land manager.

Public Participation

Since kicking off the assessment phase of the forest plan revision process in January 2014, the Tonto National Forest plan revision team has been working to involve, and collaborate with, the public. Public participation for the assessment has included listening sessions, workshops, and a series of public meetings to gather local knowledge to understand how the public values the Tonto. In addition, the Tonto National Forest plan revision team has interacted with others through presentations and meetings with county planners, tribes, stakeholders, and other government entities. Formal and informal public engagement will continue through the assessment and into the plan development phase of the forest plan revision process. It is the view of the Tonto National Forest staff that shared knowledge and understanding between the Forest Service personnel and the public needs to be a continual and dynamic part of the planning effort.

Listed below is a brief description of some of our efforts to date. For more updated information including details, dates and notes of specific events please visit our website at www.fs.usda.gov/goto/tontoplan.

- January 2014: One-hour listening sessions with 91 community members and stakeholders were conducted on January 22-23, 2014 in Scottsdale, Globe, Payson, and Mesa, Arizona. These listening sessions provided information about existing collaborative potential and limitations and helped the Tonto National Forest plan revision team organize the public participation effort for the forest plan revision effort.
- March 2014: The Tonto National Forest hosted two all-day workshops attended by Tonto staff and key stakeholders on March 6, 2014 in Tempe, Arizona and March 8, 2014 in Tonto Basin, Arizona. The purpose of these workshops was to build relationships, share learning, and begin working together on a public participation strategy for forest plan revision. The Tonto forest plan revision public participation and collaboration strategy document is available on the www.fs.usda.gov/goto/tontoplan website and can be updated as needs change.
- March 2014: An internet-based collaboration tool was developed and posted to our www.fs.usda.gov/goto/tontoplan website (Public Involvement). The link displayed questions that helped the plan revision team develop parts of the social, cultural, and economic sections of the assessment.
    - What benefits do you receive from the Tonto National Forest? Have these benefits changed over time? How do you think these benefits will change in the next 15-20 years?
    - What is unique and special about the Tonto National Forest? If you could take only one picture of the national forest, what would it be?

  - ♦ What are your favorite places to recreate on or near the Tonto National Forest?
  - ♦ Are there other issues in your community or on the Tonto National Forest that should be considered in the Assessment Report?
  - ♦ Please share any relevant datasets, research or information related to the Tonto National Forest that could be helpful to the Assessment Report or plan revision process (please include contact organization or contact person, if known).

- May-July 2014: The Tonto staff hosted eight community forums in Mesa, Payson, Roosevelt, Globe, Cave Creek, and Young, Arizona. The forums involved presentations from Tonto National Forest staff and partners on key forest plan topics, followed by small group discussions to bring forth technical and local knowledge about these topics. Notes from these meetings can be found on our website www.fs.usda.gov/goto/tontoplan. These topics and discussions were used to help us generate our key ecosystem services (see Volume II Assessment Report of Social and Economic Conditions, Trends, and Risks to Sustainability for more information). Some examples of discussion topics were concerns of a decrease in watchable wildlife opportunities across the Tonto as well as an understanding that adaptive management is important for the health of the ecosystem and to continue moving in this direction.
- October 6-10, 2014 – Voces, LLC, a New Mexico corporation contracted to help build relationships with our Latino Communities, conducted an assessment of the surrounding Latino community and their knowledge of and connection to the Tonto National Forest. They interviewed 28 people in the Phoenix and Globe-Miami and Superior areas and 22 of them were key leaders in the Hispanic and Latino community. Based on information gathered during that week, they generated a summary report with suggestions on how the Tonto National Forest could better reach and engage the Latino community. Voces, LLC took these interviews and identified four main barriers of use. They presented this information to members of the Tonto National Forest leadership and planning teams. Based on this feedback, an internal all-day workshop was held on July 21, 2015. The goal was to help build the Tonto's collaborative capacity with Latino communities and the organizations that serve them.
- November 2014 and February 2015: Information was supplied at community bulletin boards throughout the valley and across the Tonto National Forest. Our goals was to share information and direct the public to our website where continuously updated material is presented.
- November 2014 – December 2016: The Tonto National Forest staffed a forest plan revision information booth at over 80 fairs, farmers markets, conferences, and other events. The focus of these events was to educate and inform the public about the plan revision process and ways to get involved. These outreach efforts will continue throughout the planning process in various locations in and around Tonto National Forest communities. See the plan revision website at www.fs.usda.gov/goto/tontoplan to join us at our next event.
- December 8, 2014: A letter was sent out to the entire mailing list asking recipients to share relevant datasets, research, or information related to the Tonto National Forest that would be helpful to include in the assessment report. It also provided an updated status, reintroduced the plan revision website, and discussed ways to participate moving forward.
- January 2016 – December 2016: Frequent email updates were sent to our mailing list to introduce new members of the forest plan revision team and inform the public of our next steps. The updates reinforced the plan revision website and mentioned ways to participate moving forward.

- September – October 2016: The Tonto National Forest hosted seven "Needs for Change" public meetings to discuss the key findings from the draft assessment and collaborate on needs for change. This discussion was focused on eleven key themes ranging from ecological sustainability; social, cultural, and economic sustainability; and forestwide management. Discussion from these meetings helped shape the "Needs for Change" statements.

The efforts listed above helped the Tonto National Forest plan revision team better connect and relate with the public. They were able to speak to us about what they have experienced in the past, as well as any fears they may have about getting involved in the plan revision process. From this, we developed a strategy to collaborate moving forward. From their feedback, we geared our first round of public meetings around education on the 15 topics discussed in the assessment phase of the plan revision process. The two grassroots efforts mentioned (the last two bullets) helped connect the surrounding community to the Tonto National Forest. To date, over 900 individuals of all ages have been spoken to at the information booths listed above. From these personal connections, we have been able to constantly acquire new members for our mailing list and been able to promote working groups already occurring on the Tonto to help collaborate with our plan revision efforts.

Public involvement and collaboration will continue to be an integral part of the planning process over the next several years of the forest plan revision process. The Tonto National Forest planning staff is becoming more active in participating and attending other county planning efforts to understand their concerns in relation to forest plan management.

Tribal Engagement

Tribal engagement efforts for the Tonto National Forest plan revision process has been conducted with various approaches since the initial kick-off. Consultation with tribes consisted of formal letters and phone calls to all tribal groups with ancestral ties to the national forest (see list below). This was followed up with in-person meetings with the forest tribal relations liaison, forest planner, forest archaeologist, forest supervisor and/or deputy forest supervisor along with various Tribal members for seven of the thirteen Tribes with whom we consult. The goal was to begin discussions with the Tribes to seek their engagement and understand their concerns about forest management.

- December 16, 2013: Letters went out to initiate early engagement with each tribe.
- January 23, 2014: Meetings with the White Mountain Apache, Tonto Apache, and Yavapai Apache Tribes.
- January 30, 2014: Meeting with members of the Salt River Pima-Maricopa and Gila River Indian communities.
- April 1, 2014: Meeting with the Pueblo of Zuni.
- July 23, 2014: Meeting with the Hopi Tribe.
- December 8, 2014: Letters went out to request relevant data that would help the assessment and link the Tribes to our forest plan revision webpage for more information.
- August 8, 2016: Meeting with members of the Salt River Pima-Maricopa and Gila River Indian communities.
- November 8, 2016: Letter went out to gather input into the wild and scenic rivers process from the Tribes.
- November 29, 2016: Meeting with the Fort McDowell Yavapai Nation and Yavapai – Prescott Indian Tribe

- December 9, 2016: Meeting with the White Mountain Apache, Tonto Apache, San Carlos Apache, Mescalero Apache, and Yavapai Apache Tribes.
- December 13, 2016: Meeting with the Pueblo of Zuni
- December 30, 2016: Meeting with members of the Salt River Pima-Maricopa and Gila River Indian communities.

During this same time, the Tonto National Forest archaeologist, in working with the Tribes, helped to pull together a list of plant species for which they have expressed concern. The list of any wildlife or fish about which they are concerned has not been developed. Many of the Tribes who consider the Tonto National Forest an important place, both spiritually and culturally, have a strong interest in the management of the Tonto's natural resources. Tonto National Forest personnel will continuously seek to engage with Tribes through the plan revision process.

Chapter 2. Ecological Integrity and Sustainability

An ecosystem is a spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of the abiotic environment within its boundaries (36 CFR 219.19). Ecosystem or ecological integrity is the quality or condition of an ecosystem, when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence. Ecosystem sustainability is the capability of an ecosystem to meet the needs of the present generation, without compromising the ability to meet their needs of future generations. Ecosystem sustainability refers to the capability of ecosystems to maintain ecological integrity (36 CFR 219.19).

Structure

The ecological assessment is broken into the following seven sections to fully address the ecological integrity and sustainability of the Tonto National Forest. Each section's resource area is assessed to understand current conditions and trends and identify key characteristics at risk for a loss of ecological integrity.

1. **Terrestrial Ecosystems** are assessed for ecosystem integrity to determine whether terrestrial ecosystems (upland vegetation and soils) are functioning normally and are uncompromised.
2. **Riparian Ecosystems** are assessed for ecosystem integrity to determine whether riparian ecosystems (plant, animal, and aquatic communities directly or indirectly attributed to water-induced or water-related factors) are functioning normally and are uncompromised.
3. **Watersheds and Water Resources** are assessed for ecosystem integrity to determine the status of watersheds and water resources (surface and groundwater) and their role in sustaining the structure and function of terrestrial, riparian, and aquatic ecosystems on the Tonto National Forest.
4. **At-risk Species** are identified and assessed to understand the ecological conditions necessary to sustain them.
5. **Air Quality** is described and assessed through existing conditions and trends of airshed conditions and air quality.
6. **Climate Change** predictions are summarized in relation to the range of climatic conditions that have supported ecosystems in the past.
7. **Carbon Stocks** contains a baseline assessment of carbon stocks within ecosystems for the Tonto National Forest, including biomass, carbon emissions, and soil organic carbon.

Each section culminates by summarizing the risk to ecological integrity to help determine ecological need for change. There is an ecological need for change for characteristics that show a potential for risk due to ongoing conditions and trends.

The ecological assessment includes characterizations of current condition and trend for specific ecosystem characteristics. For each characteristic, the following information is evaluated, where available:

- Reference condition
- Deviation of current condition from reference condition (departure)
- Predicted future departure (trend)

Departure from reference condition is equivalent to a loss of ecological integrity. To determine a loss of integrity, current departure and departure trend are considered.

Some systems have characteristics that do not lend themselves to the historic reference condition and system integrity approach, such as air quality and water quality and quantity. For these systems and characteristics, an alternative approach will be used and discussed in each resource area's respective section.

Key Ecosystem Characteristics

Ecological integrity is simple in concept to define but more difficult in practice to assess. Ecosystem characteristics are specific components of ecological conditions that sustain ecological integrity (Forest Service Handbook 1909.12 chapter 14). A key ecosystem characteristic describes the composition, structure, connectivity, and function of an ecosystem that is most dominant. Key ecosystem characteristics are identified and evaluated for each ecosystem, but not all possible characteristics of ecosystems are identified. Only those characteristics needed to provide ecological conditions necessary to maintain or restore the ecological integrity of terrestrial, aquatic, and riparian ecosystems in the plan area are considered in the assessment (36 CFR 219.8). A limited suite of ecosystem characteristics are selected to assess ecological integrity based on the following:

- Information was readily available;
- Characteristic is relevant to key issues and sensitive to drivers and stressors; and
- Characteristics represent elements needed to assess other resource areas (for example, at-risk species and habitat).

The process for identifying and selecting key ecosystem characteristics will be iterative throughout the assessment and will be influenced by information provided by public and governmental participation.

System Drivers and Stressors

System drivers are processes that act on ecosystem characteristics, such as natural vegetation succession, natural disturbance regimes (for example, wildfire and wind), predominant climatic regimes, and broad-scale system drivers or disturbance regimes (wildfire, flooding, and insect and disease). Disturbance regimes (such as fire and wind) and stressors are both drivers, as are climate, succession, and insect and disease. Typically, disturbance regimes are characteristic disturbances and processes for that system.

Stressors are factors that may directly or indirectly degrade or impair ecosystem composition, structure, or ecological process in a manner that may impair its ecological integrity, such as an invasive species, loss of connectivity, or the disruption of a natural disturbance regime (36 CFR

219.19). A stressor can be a driver that is new to the system (for example, invasive species or climate change) or a driver that is uncharacteristic or has a disproportionately undesirable outcome (for example, uncharacteristic wildfire or insect infestations and disease).

Specific system drivers and stressors are identified and evaluated in the context for each primary resource area.

Spatial Scales of Analysis

The area of analysis for the assessment should be large enough to capture broad-scale trends and the natural range of variation in disturbance intensity, frequency, and areal extent. For most characteristics, it is valuable to consider multiple scales for the assessment. The assessment evaluates ecological integrity and ecosystem characteristics at three spatial scales:

- **Context scale** is needed to put the Tonto National Forest condition in context with the greater area, including lands beyond the Tonto National Forest boundary. The status and distribution of resources at the context scale may inform ecological need for change based on the potential for National Forest System lands to contribute to overall integrity.
- **Plan scale** shows current condition and trends as an average of conditions across the Tonto National Forest.
- **Local scale** is valuable for describing departure patterns for a given characteristic and identifying where particular issues may need attention and drive forest plan components. This scale is not as likely to drive ecological need for change but may drive development of plan components.

The goal of evaluating information about ecological integrity at scales broader than the plan area is to understand the context of management for resources within the plan area. An understanding of the environmental context extending beyond the plan area should be useful in determining opportunities or limitations for National Forest System lands to contribute to the sustainability of the broader ecological systems, as well as the impacts of the broader landscape on the sustainability of resources within the plan area. In some instances, a unique role of National Forest System lands may become apparent at this scale.

Reference Conditions

Reference conditions are the environmental conditions that infer ecological sustainability. When available, reference conditions are represented by the natural range of variation, not the total range of variation, prior to European settlement and under the current climatic period. For many ecosystems, the natural range of variation also reflects human-caused disturbance and effects prior to settlement. It may also be necessary to refine reference conditions according to contemporary factors (for example, invasive species) or projected conditions (for example, climate change). Reference conditions are most useful as an inference of sustainability when they have been quantified by amount, condition, spatial distribution, and temporal variation.

For many ecosystems, the natural range of variation provides insight into the temporal dynamics and key characteristics of ecological systems and therefore helps to evaluate ecological integrity. The natural range of variation is a tool for assessing ecological integrity of terrestrial, riparian, and aquatic ecosystems, and does not necessarily constitute a management target or desired condition. The natural range of variation can help identify key structural, functional, compositional, and connectivity characteristics, for which plan components may be important for either maintenance or restoration of such ecological conditions.

In some situations, there is not enough information about selected key ecosystem characteristics to understand the reference conditions under historical disturbance regimes. In these cases, ecological integrity is evaluated based on the current understanding of conditions that would sustain these key ecosystem characteristics (Forest Service Handbook 1909.12, chapter 10, section 12.15b).

Assessing Risk to Ecological Integrity

Risk summarizes threats to ecological integrity from unsustainable levels of stressors, either current or predicted. The risk of losing integrity of each key ecosystem characteristic is integrated geographically to quantify overall risk to the system. Risk is assessed on National Forest System lands, as it relates to systems and processes that are under agency control and/or authority. However, to fully understand risk to those lands, systems, and processes, they are assessed in the context of the larger landscape to the extent possible. An understanding of the environmental context extending beyond the plan area should be useful in determining opportunities or limitations for National Forest System lands to contribute to the sustainability of the broader ecological systems, as well as the impacts of the broader landscape on the sustainability of resources within the plan area. In some instances, a unique role of the National Forest System lands may become apparent at this scale (Forest Service Handbook 1909.12, chapter 10, section 12.13b).

The risk to ecological integrity was assessed for each ecosystem characteristic by weighing the current deviation from reference condition against the trend for that resource, as conceptualized in a decision matrix (figure 2). A risk can be mitigated if the departure is due to ongoing activities, the characteristic is within agency authority and control, and the trend and condition can be improved (reversible).

Deviation from Reference Condition	Major Stressor[1]	Trend: Toward Reference Condition	Trend: Stable	Trend: Away from Reference Condition
Significant Deviation	NO	**Risk Addressed** Continue current management and identify restoration opportunities	**Legacy of Past Mgmt** OR **Deviation due to Current Mgmt (ongoing activities)** Evaluate system reversibility and threats	**Potential for High Risk** Evaluate system reversibility and threats
No Significant Deviation	NO		**No Risk** Continue current management	**Potential Risk** Evaluate magnitude of future deviations, threats, and reversibility

Figure 2. Matrix to assess risk to ecological integrity

Chapter 3. Terrestrial Ecosystems

Terrestrial ecosystems are assessed using key ecosystem characteristics related to vegetation and soils. To evaluate ecological integrity, vegetation and soils on the Tonto National Forest are subdivided into smaller ecosystem types based on ecosystem potential and typical disturbances. This section assesses current and expected future departure (the degree to which the integrity of a system has been compromised) by comparing the results of current Tonto National Forest management to a defined reference condition for each ecosystem type.

Ecological Response Units and Terrestrial Ecosystem Units

The assessment of terrestrial ecosystem condition is stratified using the ecological response unit system, which is a classification of sites with similar plant species composition, succession patterns, and disturbance regimes. The ecological response units are constructed, in concept and resolution, such that they are applicable to management decisions. The Forest Service has previously employed the ecological response unit concept in successful landscape analysis and strategic planning in the Southwestern Region.

The ecological response unit framework describes all major ecosystem types found in the region based on a coarse stratification of biophysical themes. The ecological response units are mapped technical groupings of finer vegetation classes with similar site potential and disturbance history. They display ranges of plant associations (USDA Forest Service 1997) along with structure and process characteristics that would occur when natural disturbance regimes and biological processes prevail (Schussman 2006). Similar to LANDFIRE biophysical settings (NIFTT 2010), ecological response units combine themes of site potential and historic fire regime:

Ecological Response Unit = Site Potential + Historical Disturbance Regime

Each ecological response unit characterizes sites with similar composition, structure, function, and connectivity and defines their spatial distribution on the landscape. Stratifying terrestrial ecosystems based on vegetation characteristics and function is appropriate for two reasons. First, vegetation is the primary terrestrial and biological ecosystem component that is manipulated through management and affected by natural processes. Second, it represents habitat for wildlife and provides the required link to species diversity. The section on at-risk species, found later in this volume, is based on these ecological response units, ecosystem characteristics, and ecological integrity.

Terrestrial ecosystems are comprised of upland vegetation or vegetation communities that are not located near or influenced by streams or wetlands. Riparian ecosystems are discussed as a separate resource in this assessment. Upland ecological response units on the Tonto National Forest are derived from the terrestrial ecosystems survey of the Tonto National Forest, an inventory of soil types or terrestrial ecosystem units. Terrestrial ecosystem units relate to combinations of soils, land types, and vegetation communities. They are summarized, by ecological response unit, for some key ecosystem characteristics, particularly those that are soil related. Only ecological response units that make up at least one percent of the Tonto National Forest are analyzed (table 1).

Table 1. Ecological response units (ERUs) analyzed on the Tonto National Forest

System Type	ERU Code	ERU Name	Acres on Tonto National Forest	% of Tonto National Forest	Elevational Range (feet) on the Tonto National Forest[1]
Shrublands	SDS	Sonora-Mojave Mixed Salt Desert Scrub	21,095	1	1,900 – 3,200
Shrublands	MSDS	Mohave Sonoran Desert Scrub[2]	770,189	28 [3]	1,300 – 5,800
Shrublands	MSDS (CB)	Sonora-Mojave Creosote-Bursage Desert Scrub	54,423	2	1,300 – 3,300
Shrublands	MSDS (SOS)	Sonoran Mid-Elevation Desert Scrub	113,557	4	1,700 – 5,100
Shrublands	MSDS (SP)	Sonoran Paloverde-Mixed Cactus Desert Scrub	602,209	22	1,300 – 5,800
Shrublands	IC	Interior Chaparral	290,771	11	2,300 – 7,800
Grasslands	SDG	Semi-Desert Grassland	340,983	12	1,800 – 6,800
Woodlands	PJO	Pinyon-Juniper Woodland	54,352	2	2,300 – 7,300
Woodlands	JUG	Juniper Grass	415,546	15	2,200 – 7,600
Woodlands	MEW	Madrean Encinal Woodland	93,157	3	3,400 – 6,700
Woodlands	PJC	Pinyon-Juniper Evergreen Shrub	398,154	14	2,400 – 7,800
Woodlands	PJG	Pinyon-Juniper Grass	74,240	3	3,400 – 7,000
Forests	PPE	Ponderosa Pine - Evergreen Oak	205,729	7	5,500 – 7,200
Forests	PPF	Ponderosa Pine Forest	37,878	1	5,500 – 7,600
Forests	MCD	Mixed Conifer - Frequent Fire	58,829	2	6,100 – 10,000

1 Elevation ranges were calculated by intersecting the ecological response unit layer and 30-meter Landsat digital elevation model layer for the Tonto National Forest using a geographic information system (GIS).

2 MSDS values are displayed for both class (MSDS) and subclasses (CB, SOS and SP).

3. Percent is total of all MSDS subclasses listed in following three rows.

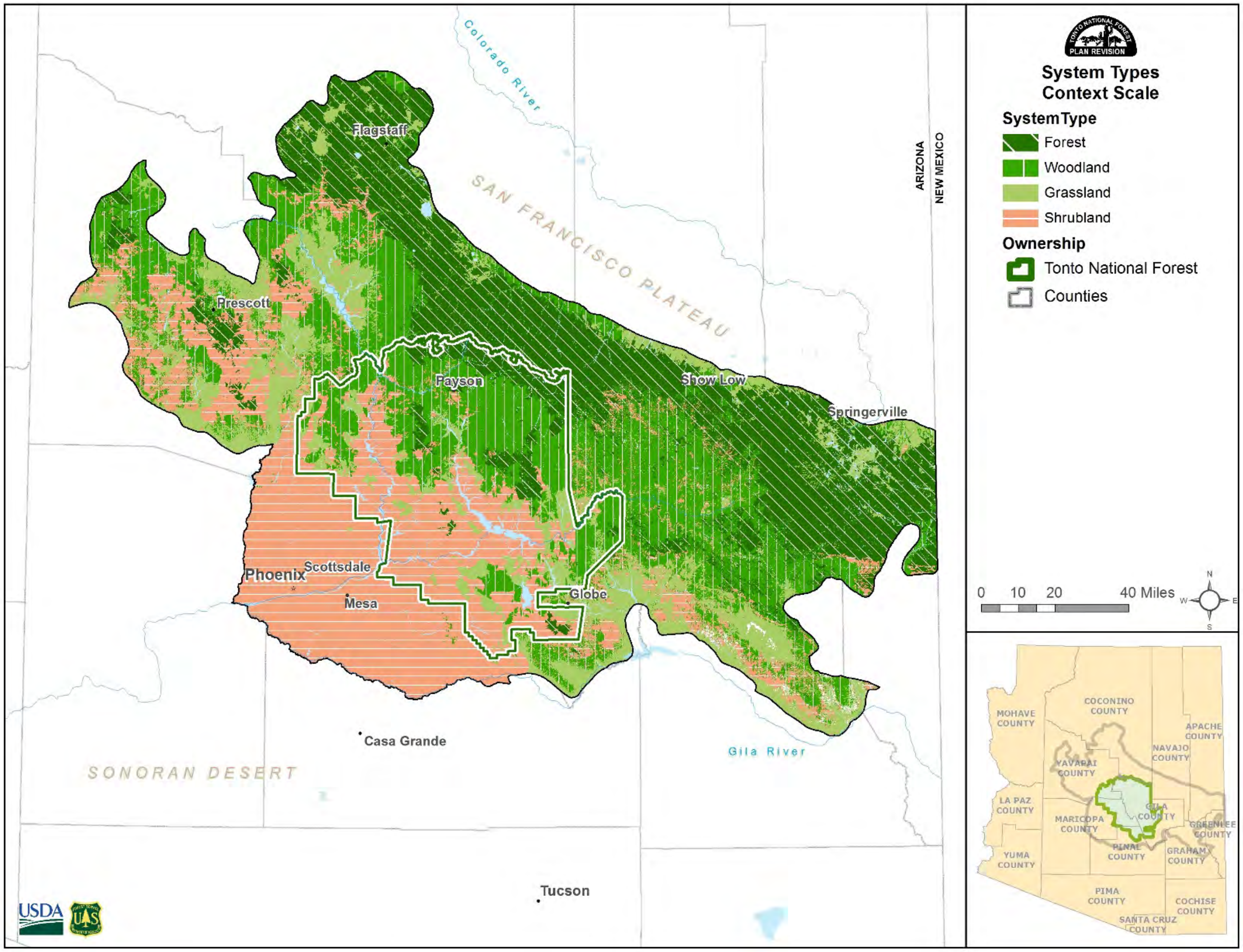


Figure 3. Ecological response units by system type at plan (national forest boundary) and context scales

Spatial Scales of Analysis for Terrestrial Ecological Systems

Different spatial scales provide resolution across both the greater landscape and localized conditions, helping assess whether ecological sustainability of each ecological community are being met. Knowledge of the ecological integrity in the plan area and at scales broader than the plan area is important to identify opportunities or limitations for lands in the plan area to contribute to the integrity of the broader ecological systems, as well as the impacts of the broader landscape on the sustainability of resources within the plan area. In some instances, a role of the plan area may become apparent at this scale.

Fine scales allow us to detect small, yet meaningful, features of the landscape while broad scales identify important patterns over the larger spatial extent. Different ecological patterns emerge at different scales of analysis since landscapes are nested within continuously larger landscapes. For example, canopy cover can look very different at three spatial scales. At the local (fine) scale the presence of only a few single trees and some pockets or groups of trees indicates an open or sparse, canopy cover. However, as we scale up to the plan scale, canopy cover looks a little denser, especially right around the extent of the local scale. At the context scale, the pattern of small patches of trees amid large natural meadows and grasslands is visible. These scales are especially important when we consider the diversity of organisms that inhabit these ecosystems. For example, the Mexican spotted owl requires habitat which can extend from a few stands to potentially an entire ecoregion. In this section, terrestrial systems are analyzed at the context, plan (Tonto National Forest boundary), and local scales. The context scale provides a “big picture” of overall sustainability across the larger area. Descriptions at the plan and local scales provide additional detail necessary for identifying areas of concern and potentially driving the ecological need for change in current management, in implementation of future projects and activities, or both.

Context Scale

Ecoregion subsections (Cleland et al. 2007) were used to define the context scale for the assessment of vegetation and soil. The extent of all ecological subsections which intersect the Tonto National Forest administrative boundary were used to define the context scale, with two exceptions. The Gila Bend Desert Shrubland subsection was clipped at the Gila River to bound the context area to the south and at the Agua Fria River to bound the context area to the west. The White Mountains Coniferous Forest subsection was clipped at the New Mexico state line, bounding the context area to the east (figure 4)

Plan and Local Scale

The plan scale consists of the entirety of the Tonto National Forest, bounded by its administrative boundary. The local scale is valuable for describing departure patterns within the plan scale for a given characteristic and identifying where issues may warrant specific attention and drive forest plan components. This scale is not as likely to drive ecological need for change but may drive development of plan components. The local scale of analysis consists of fourth-level watersheds. Watersheds that contained less than 10 percent on the Tonto were incorporated into an adjoining 4^{th}-level watershed (figure 4). When information is available, key ecosystem characteristics are assessed at the local scale. Table 2 shows the distribution of ecological response units at all scales of analysis. Information in cells with marginally represented ecological response units (low proportion) should be considered accordingly, it may reflect a small sample size rather than actual conditions.

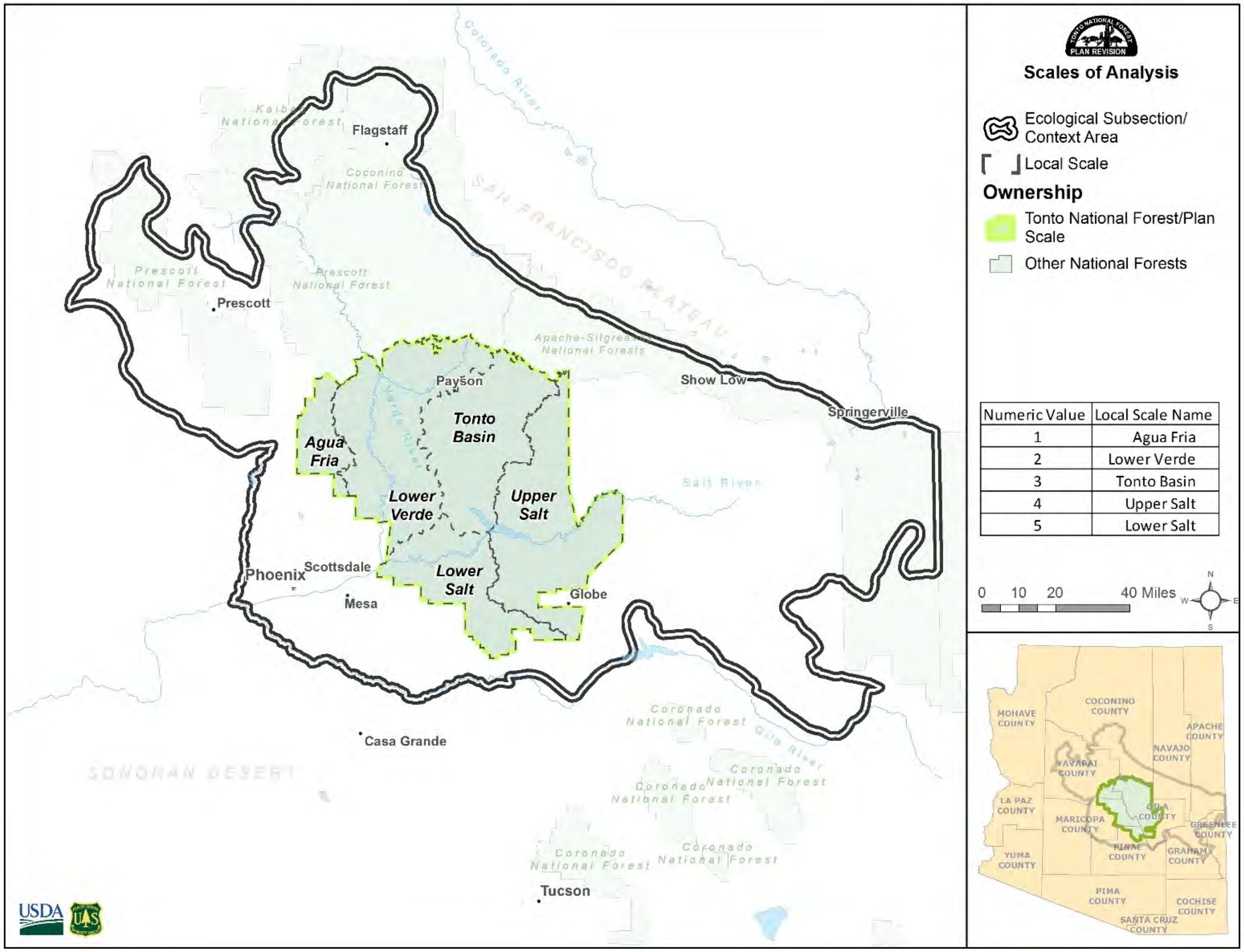


Figure 4. Scales of analysis for terrestrial vegetation

Table 2. Ecological response unit (ERU) distribution (acres and percent) at all scales of analysis (shaded cells represent ecological response units that make up less than one percent of the scale)

ERU Code	Ecological Response Unit Name	Context	Plan	1 Agua Fria Local Scale	2 Lower Verde Local Scale	3 Tonto Basin Local Scale	4 Upper Salt Local Scale	5 Lower Salt Local Scale
SDS	Sonora-Mojave Mixed Salt Desert Scrub	319,354 **3%**	21,095 **1%**	0 **0%**	2,387 **0.30%**	12,091 **1.90%**	6,616 **0.90%**	0 **0%**
MSDS (CB)	Sonora-Mojave Creosote-Bursage Desert Scrub	1,376,676 **11%**	54,423 **2%**	3,295 **1.90%**	14,852 **1.90%**	0 **0%**	8,521 **1.10%**	27,756 **6.40%**
MSDS (SOS)	Sonoran Mid-Elevation Desert Scrub	114,344 **1%**	113,557 **4%**	1,054 **0.60%**	56,256 **7.30%**	24,972 **4.00%**	26,403 **3.50%**	4,873 **1.10%**
MSDS (SP)	Sonoran Paloverde-Mixed Cactus Desert Scrub	624,610 **5%**	602,209 **22%**	22,230 **13.10%**	198,719 **25.80%**	39,195 **6.30%**	85,543 **11.20%**	256,523 **58.90%**
IC	Interior Chaparral	1,300,963 **11%**	290,771 **11%**	29,135 **17.20%**	50,473 **6.50%**	45,699 **7.40%**	93,036 **12.20%**	72,427 **16.60%**
SDG	Semi-Desert Grassland	1,718,290 **14%**	340,983 **12%**	42,283 **24.90%**	56,117 **7.30%**	42,337 **6.80%**	148,129 **19.40%**	52,118 **12.00%**
PJO	Pinyon-Juniper Woodland	276,149 **2%**	54,352 **2%**	289 **0.20%**	32,503 **4.20%**	13,582 **2.20%**	7,978 **1.00%**	0 **0%**
JUG	Juniper Grass	647,511 **5%**	415,546 **15%**	62,022 **36.50%**	158,517 **20.50%**	91,348 **14.70%**	99,753 **13.10%**	3,906 **0.90%**
MEW	Madrean Encinal Woodland	154,815 **1%**	93,157 **3%**	0 **0%**	10,938 **1.40%**	67,375 **10.90%**	14,823 **1.90%**	21 **< 0.10%**
PJC	Pinyon-Juniper Evergreen Shrub	1,875,546 **15%**	398,154 **14%**	8,719 **5.10%**	90,131 **11.70%**	133,208 **21.50%**	151,777 **19.90%**	14,319 **3.30%**
PJG	Pinyon-Juniper Grass	612,017 **5%**	74,240 **3%**	720 **0.40%**	8,180 **1.10%**	33,728 **5.40%**	31,612 **4.10%**	0 **0%**
PPE	Ponderosa Pine - Evergreen Oak	532,841 **4%**	205,729 **7%**	63 **0%**	68,396 **8.90%**	70,885 **11.40%**	62,835 **8.20%**	3,550 **0.80%**
PPF	Ponderosa Pine Forest	2,137,070 **18%**	37,878 **1%**	0 **0%**	0 **0%**	13,966 **2.30%**	23,912 **3.10%**	0 **0%**
MCD	Mixed Conifer - Frequent Fire	423,765 **3%**	58,829 **2%**	0 **0%**	24,090 **3.10%**	32,101 **5.20%**	2,639 **0.30%**	0 **0%**

Terrestrial Ecosystem Spatial Niche

The spatial niche analysis relates the Tonto National Forest to its surroundings. Spatial niche is dependent on the relative distribution of an ecological response unit, as well as the relative distribution of departure within that ecological response unit. Departure from the reference distribution is quantified by comparing it to the actual current distribution. The closer composition, structure, and process are to their historic conditions, the more the system is maintaining ecological integrity and the more resilient it will be to stress. The contribution of the Tonto National Forest to the ecological integrity of an ecological response unit in the context of the surrounding landscape is dependent first on the percent of the Tonto occupied by the ecological response unit. The Tonto's contribution to integrity also depends on the percent of the context landscape occupied by the ecological response unit and the relative representation of the ecological response unit on-forest to off-forest (proportional representation).

The codes for the ecological response units in the following two figures are as follows:

IC Interior Chaparral
JUG Juniper Grass
MEW Madrean Encinal Woodland
MCD Mixed Conifer - Frequent Fire
PJC Pinyon Juniper Evergreen Shrub
PJG Pinyon Juniper Grass
PJO Pinyon Juniper Woodland
PPE Ponderosa Pine - Evergreen Oak
PPF Ponderosa Pine Forest
SDG Semi-Desert Grassland
SDS Sonora-Mojave Mixed Salt Desert Scrub
MSDS-CB Sonora-Mojave Creosote-Bursage Desert Scrub
MSDS-SOS Sonoran Mid-Elevation Desert Scrub
MSDS-SP Sonoran Paloverde-Mixed Cactus Desert Scrub

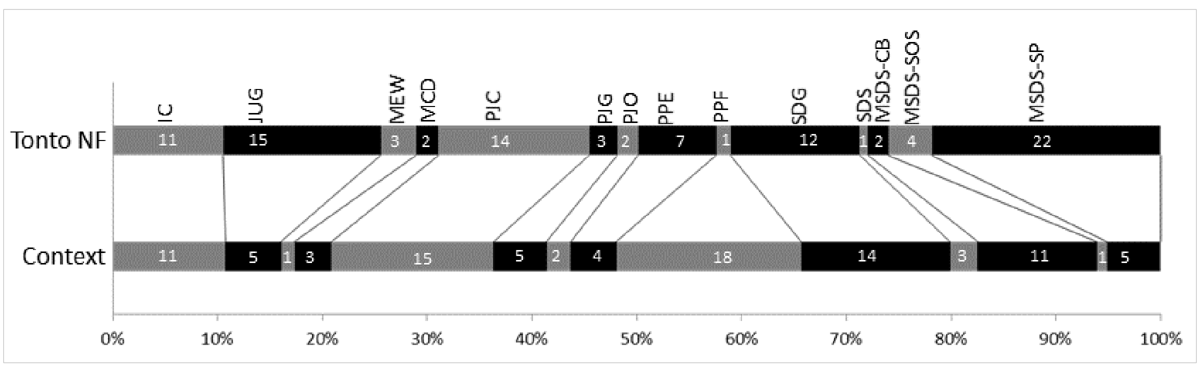


Figure 5. Ecological response unit distribution and representation at plan (Tonto National Forest) and context scales

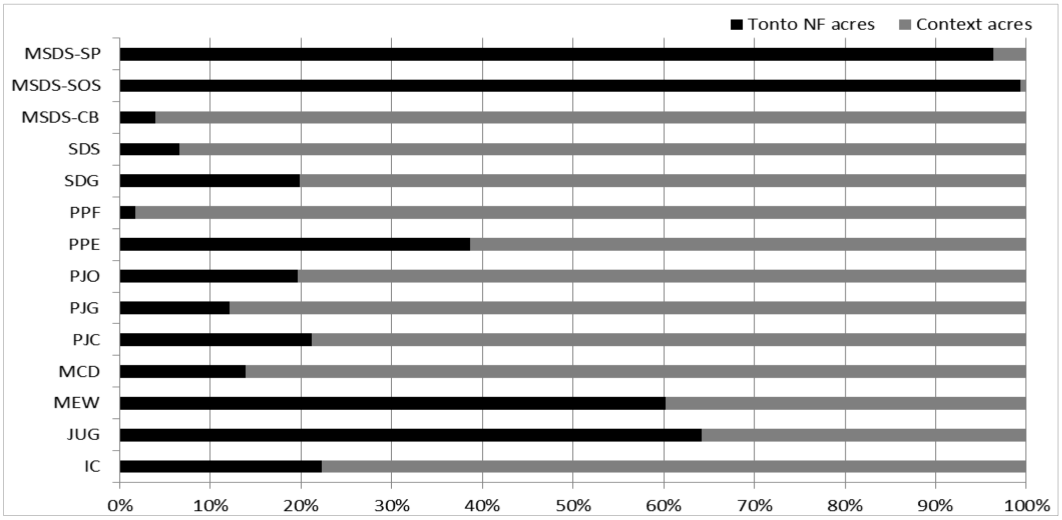


Figure 6. Acres distributed between the plan scale and context scale (excluding plan acres)

The Tonto's contribution to the context for each ecological response unit is shown in table 3. The Tonto makes up 23 percent of the context landscape by area. When an ecological response unit is more common at the plan scale than would be expected based on area (greater than 23 percent of the total ecological response unit in the context landscape), the plan area has a disproportionate influence on sustainability of the system or greater proportional representation. Ecological response units that are rare at the context scale will be influenced more by conditions at the plan scale than ecological response units that are more abundant, for which plan scale conditions may be overwhelmed by conditions outside the boundaries of the Tonto National Forest.

$$Proportional\ representation = \frac{\%\ of\ Tonto\ National\ Forest - \%\ of\ Contect\ Landscape}{\%\ of\ Tonto\ National\ Forest + \%\ of\ Context\ Landscape}$$

Positive values indicate the proportion of the Tonto National Forest is greater than the proportion of the context (the ecological response unit is more common on the Tonto). Negative values indicate the opposite (the ecological response unit is less common on the Tonto). A value of one means the ecological response unit is only represented on the Tonto National Forest with no acres at the context scale. A value of negative one means the ecological response unit is only represented at the context scale with no acres on the Tonto National Forest. A value of zero means the percent of the Tonto covered by an ecological response unit is the same as the percent of the context landscape covered by that ecological response unit.

Opportunity for the Tonto National Forest to influence the context landscape is captured in table 3. The proportional representation identifies the relative spatial significance of ecosystems found on the Tonto to the greater landscape. Ecosystems such as Juniper Grass, Madrean Encinal Woodland, Ponderosa Pine - Evergreen Oak, Sonoran Paloverde-Mixed Cactus Desert Scrub, and Sonoran Mid-Elevation Desert Scrub have high proportional representation meaning the sustainability of these systems at the context scale is more sensitive to conditions at the plan scale, and the Tonto National Forest has a significant role in restoring or maintaining integrity of these systems. On the other hand, ecosystems such as Ponderosa Pine Forest and Sonora-Mojave Creosote-Bursage Desert Scrub are less common at the plan scale, and the Tonto has less opportunity to influence context scale conditions.

In the table, green shading indicates low departure (0 to 33 percent), yellow shading indicates moderate departure (34 to 66 percent), and red shading indicates high departure (67 to 100 percent). For more information, see "Seral State Proportion" section. Cells with an asterisk (*) identify high potential for the Tonto National Forest to contribute to the sustainability of these ecosystems.

Table 3. Terrestrial ecosystem spatial niche

ERU	Tonto NF acres, %	Context acres, %	Plan contribution to context[2]	Proportional representation	Plan seral state departure	Context seral state departure
SDS	21,095 0.8%	319,354 2.6%	6.6%	-0.55	7	--
MSDS (CB)	54,423 2.0%	1,376,676 11.4%	4.0%	-0.70	3	0
MSDS (SOS)	113,557 4.1%	114,344 0.9%	99.3%	0.63*	52	53
MSDS (SP)	602,209 21.8%	624,610 5.2%	96.4%	0.62*	9	9
IC	290,771 10.5%	1,300,963 10.7%	22.4%	-0.01	30	10
SDG	340,983 12.3%	1,718,290 14.2%	19.8%	-0.07	94	78
PJO	54,352 2.0%	276,149 2.3%	19.7%	-0.07	30	23
JUG	415,546 15.0%	647,511 5.3%	64.2%	0.47*	65	56
MEW	93,157 3.4%	154,815 1.3%	60.2%	0.45*	43	40
PJC	398,154 14.4%	1,875,546 15.5%	21.2%	-0.04	76	54
PJG	74,240 2.7%	612,017 5.1%	12.1%	-0.31	35	42
PPE	205,729 7.4%	532,841 4.4%	38.6%	0.26*	73	71
PPF	37,878 1.4%	2,137,070 17.6%	1.8%	-0.86	95	95
MCD	58,829 2.1%	423,765 3.5%	13.9	-0.24	62	73

1. IC – Interior Chaparral, JUG – Juniper Grass, MEW – Madrean Encinal Woodland, MCD – Mixed Conifer - Frequent Fire, PJC – Pinyon Juniper Evergreen Shrub, PJG – Pinyon Juniper Grass, PJO – Pinyon Juniper Woodland, PPE – Ponderosa Pine - Evergreen Oak, PPF – Ponderosa Pine Forest, SDG – Semi-Desert Grassland, SDS – Sonora-Mojave Mixed Salt Desert Scrub, MSDS (CB) – Sonora-Mojave Creosote-Bursage Desert Scrub, MSDS (SOS) – Sonoran Mid-Elevation Desert Scrub, MSDS (SP) – Sonoran Paloverde-Mixed Cactus Desert Scrub.

Highly departed ecological response units are of greater concern because existing ecological integrity is already low. These may also indicate a priority for restoration. The relative departure between the two scales also assists in identifying potential refuge especially if conditions are significantly different between the two scales.

The Pinyon-Juniper Evergreen Shrub ecological response unit is similarly distributed at the plan and context scales (proportional representation = -0.04), but departure is much higher at the plan scale. While the sustainability of this system may be more affected by conditions at the context scale (much fewer acres on the Tonto), restoration of this ecological response unit may aid in reducing fragmentation at the broader landscape (context scale).

Over 90 percent of the context acres for Sonoran Mid-Elevation Desert Scrub and Sonoran Paloverde-Mixed Cactus Desert Scrub ecological response units are located on the Tonto National Forest. While departure is low to moderate at the plan and context scales, future conditions[1] (plan scale) show high departure; therefore, the Tonto National Forest has a significant influence on maintaining sustainability and ecological integrity of these ecological response units. Other ecological response units for which the Tonto has an influence are Juniper Grass, Madrean Encinal Woodland, and Ponderosa Pine - Evergreen Oak. These ecological response units are moderately to highly departed at both the plan and context scale; however, departure is slightly higher at the plan scale for these ecological response units. Additionally, they represent a significant proportion of the context acres (table 3).

Key Ecosystem Characteristics for Terrestrial Vegetation

Ecosystem characteristics are specific components of ecological conditions that sustain ecological integrity. Each relates to composition, structure, and/or function of an ecosystem that is most dominant. Key ecosystem characteristics are identified and evaluated for each ecosystem, but not all possible characteristics of ecosystems are identified. Only those characteristics needed to provide ecological conditions necessary to maintain or restore the ecological integrity of terrestrial ecosystems in the plan area are considered in the assessment (36 CFR 219.8). Ecosystem characteristics were selected based on information that was readily available, characteristic is relevant to key issues and sensitive to drivers and stressors, and characteristics represent elements needed to assess other resource areas (for example, at-risk species and habitat). Not all ecosystem characteristics are applicable to all ecological response units. For example, dead fallen (coarse woody debris) or standing trees (snags) are not relevant or applicable for grassland and shrubland ecological response units. The key ecosystem characteristics for terrestrial vegetation (ecological response units) are:

- Seral state proportion
- Similarity to site potential
- Vegetative ground cover
- Coarse woody debris and snag density
- Patch size
- Fire regime (fire frequency and severity)
- Fire regime condition class
- Insects and disease

Departure for Ecosystem Characteristics

Departure is a measure of deviation of current conditions from reference conditions. This departure from reference condition is equivalent to loss of ecological integrity. To determine a loss of integrity, current departure and departure trend (potential future departure) are considered, when applicable. Departure for each of the key ecosystem characteristics have been quantified and generalized into three different general categories: low (0 to 33 percent), moderate (34 to 66 percent), and high (67 to 100 percent) relative to “natural” or reference conditions.

[1] See “Seral State Proportion” analysis for further information.

Seral State Proportion

Seral state proportion is the percent of ecological response units in each seral state at context, plan, and local scales. Seral state refers to the series of biotic communities formed through the ecological process or succession of progressive change in a plant community after a stand-initiating disturbance. Each ecological response unit can manifest in a range of potential vegetative conditions, each representing a unique phase in the overall ecology of the system (Weisz et al. 2009). By grouping these phases into seral state classes with unique vegetation characteristics (composition and structure), models can be developed that define transitions among phases. These state-and-transition models can be built and adapted so that the dynamics of the system reflect natural range of variation, and the resulting distribution among state classes represents the ecological response unit reference condition (Weisz et al. 2009). These models can be further parameterized to incorporate current natural disturbances and management regimes and used to develop projections of future vegetative conditions. Reference conditions are based on Forest Service Southwestern Regional Office guidance (TNC 2006, Landfire 2010).

Data and Analysis Process

The assignment of current state class proportions uses regional satellite imagery based classifications of vegetation size class, canopy cover and dominance type at a 1:100,000 scale, with extensive photo interpretation and field data collection (Midscale Vegetation Mapping Project) (Mellin et al. 2008). Existing vegetation is assigned to an ecological response unit and then to the appropriate state class within that ecological response unit according to state class descriptions and model developed by the Forest Service Southwestern Regional Office, LANDFIRE, The Nature Conservancy, and the Integrated Landscape Assessment Project. Reference conditions are based on best available scientific information. Ecological response unit summary tables are footnoted with specific reference condition sources.

Departure from the reference distribution is quantified by comparing it to the actual current distribution and to future predicted distributions. The closer composition, structure, and process are to their historic conditions, the more the system is maintaining ecological integrity and the more resilient it will be to stress. For each state class, the similarity to reference is equal to the proportion in common that exists either on the current landscape or on the projected future landscape. The similarity value is equal to the lesser value between the current or projected proportion and the reference proportion. The sum of similarity values for an ecological response unit is 100 percent or less, and 100 percent minus the similarity value equals the departure of the ecological response unit (table 4). In the following table, the sum of lesser values is 70 percent, and the departure is 100 minus the sum of lesser values or 30 percent.

Table 4. Calculation of seral state proportion departure. This example uses model states under reference and current conditions for the Interior Chaparral ecological response unit.

Class	Seral State	Reference	Current	Lesser Value
A	Grass/Forb/Shrub	2%	10%	2%
B	Mid development 10-30% shrub cover (open)	5%	26%	5%
C,D	Mature (closed)	93%	63%	63%

Projections of future state class proportions are produced using the Vegetation Dynamics Development Tool (VDDT) (ESSA 2006) and state-and-transition models developed by LANDFIRE, The Nature Conservancy, and the Integrated Landscape Assessment Project and refined by the Forest Service Southwestern Regional Office with input from forest specialists.

These state-and-transition models both define seral states for each ecological response unit and allow comparison among management scenarios. For this analysis, future trend assumes the continuation of current levels of management indefinitely. Many state transition destinations and probabilities are derived from Forest Vegetation Simulator modeling (Moeur and Vandendriesche 2011; Weisz et al. 2010). Burn severity information is compiled from Monitoring Trends in Burn Severity records (Eidenshink et al. 2007). Other inputs include forest management activity (thinning, prescribed fire, etc.) data from the Forest Service Activity Tracking System and Aerial Detection Surveys conducted by the Forest Service's Forest Health Program.

By comparing regional midscale and LANDFIRE current vegetation information to reference seral state proportions, departure is calculated for the context, plan, and local scales. The Tonto National Forest only affects management at the plan scale and only collects management information on the national forest; so state-and-transition models can only be reliably parameterized at the plan scale. Therefore, future trend is modeled only at the plan scale, though trends at the context or local scale may be discussed where information suggests they differ. The trend analysis relies mostly on state-and-transition modeling results, while trend for other characteristics is addressed only when a probable trajectory can be inferred. The predictions used in the assessment are based on 10- and 100-year modeling results only. Seral state proportion trend and projections (VDDT modeling at plan scale) is summarized for each ecological response unit (table 5).

Table 5. Ecological response unit departure (in percent) by all scales and projections at plan scale

System Type	ERU code	ERU name	Departure (percent)[1]									
			Current conditions							Projections at plan scale		
					Local scale[2]							
			Context landscape	Plan scale (Tonto NF)	1: Agua Fria	2: Lower Verde	3: Tonto Basin	4: Upper Salt	5: Lower Salt	10 years	100 years	1000 years
Shrubland	SDS[3]	Sonora-Mohave Mixed Salt Desert Scrub		7						NA	NA	NA
Shrubland	MSDS (CB)[4]	Sonora-Mojave Creosote-Bursage Desert Scrub[3]	0	1	5	3		5	1	NA	NA	NA
Shrubland	MSDS (SOS)[4]	Sonoran Mid-Elevation Desert Scrub	53	52	53	46	58	40	57	NA	NA	NA
Shrubland	MSDS (SP)	Sonoran Paloverde-Mixed Cactus Desert Scrub	9	9	12	7	5	5	15	17	71	89
Shrubland	IC	Interior Chaparral	10	30	40	31	41	11	42	5	5	5
Grassland	SDG	Semi-Desert Grassland	78	94	91	93	94	95	95	94	95	100
Woodland	PJO	Pinyon-Juniper Woodland	23	30	**59***	36	29	14		28	31	32
Woodland	JUG	Juniper Grass	56	65	64	65	67	65	**88***	56	32	35
Woodland	MEW	Madrean Encinal Woodland	40	43		44	42	48	**43***	44	50	51
Woodland	PJC	Pinyon-Juniper Evergreen Shrub	54	76	86	75	72	77	84	65	49	46
Woodland	PJG	Pinyon-Juniper Grass	42	35	**35***	38	35	40		31	27	28
Forest	PPE	Ponderosa Pine - Evergreen Oak	71	73		68	74	79	**56***	52	39	39
Forest	PPF	Ponderosa Pine Forest	95	95			97	94		95	91	91
Forest	MCD	Mixed Conifer - Frequent Fire	73	62		54	75	**42***		66	62	61

1. Departure is a nominal classification: low (0 to 33 percent), green; moderate (34 to 66 percent) yellow; high (66 to 100 percent), red.
2. At the local scale, numbers in boldface type and an * mean the ecological response unit is less than 1 percent of local scale. Blank cells mean the ecological response unit is not present or sufficiently distributed at scale for analysis.
3. Data is not available at the context scale, and there are insufficient acres on the Tonto National Forest to model departure (projections at plan scale).
4. Models are currently unavailable for these provisional subclasses.

Results

Forestwide, the highest departure is among the forest types: Ponderosa Pine Forest, Mixed Conifer - Frequent Fire, and Ponderosa Pine-Evergreen Oak ecological response units. With the exception of Mixed Conifer - Frequent Fire, current conditions for Ponderosa Pine Forest and Ponderosa Pine - Evergreen Oak are nearly the same on and off the Tonto National Forest (that is, seral state departure is nearly equal between plan and context scales). The only ecological response unit showing improvement is Ponderosa Pine - Evergreen Oak where current treatments (mechanical and prescribed) are moving the state class distributions closer to reference conditions but still moderately departed after 100 years. Mixed Conifer - Frequent Fire departure is slightly lower at the plan scale (62 percent) relative to the context scale (73 percent). Fire suppression and exclusion, historic grazing and logging have been the major drivers of change in these systems (Ponderosa Pine Forest, Mixed Conifer - Frequent Fire, and Ponderosa Pine-Evergreen Oak ecological response units). These activities have resulted in stressed conditions, large patch sizes, accumulation of coarse woody debris, and a loss of structural diversity – all of which increase the risk of widespread mortality from fire, insects, and disease. Most ecological response units at the Tonto Basin local scale have the highest departure relative to all the other local scales. This local scale should be considered in setting management priorities or future planning efforts.

Forestwide, many of the woodlands have moderate to high seral state departure, specifically among the Pinyon-Juniper Evergreen Shrub ecological response unit. Conditions for Pinyon-Juniper Evergreen Shrub are moderately departed at the context scale (54 percent departure) but noticeably better than conditions on the Tonto (76 percent departure). The higher departure on the Tonto relative to the context area is the result of more acres are in closed-canopy states compared to the context area. Large fires, such as the Cave Creek Complex fire, have also resulted in more acres in grass/forb/shrub states (38 percent) than reference condition (5 percent) – another factor contributing to high departure. Overtime, projections show lower departure because the grass/forb/shrub states will move into the medium and large open states with seral state proportions trending more towards reference conditions. For some woodlands, such as the Pinyon-Juniper Woodland ecological response unit, fire exclusion has had little effect on seral state departure because fire return intervals are naturally very long. Instead, drought and insect outbreaks have been major contributors to recent changes in these communities and is likely the cause for the moderate departure for the Pinyon-Juniper Woodland ecological response unit at the Agua Fria and Lower Verde local scales on the Tonto.

Similar to the Ponderosa Pine ecological response unit, the Semi-Desert Grassland ecological response unit has one of the highest seral state departures, both at the plan and context scale, and projections at 100 years under current management show high seral state departure. The most pronounced changes to the Semi-Desert Grassland ecological response unit has been an overall shift from predominately open perennial grasslands to mixed grasslands (shrub, tree, and perennial grass) and converted shrublands. Fire suppression and exclusion, land development, and historic grazing have all contributed to shrub and tree encroachment, reduced productivity, and lowered species diversity. The altered fire regime, along with the establishment and spread of exotic grasses, are strongly influencing projections of decreased perennial grasslands. The increase in some exotics, such as Lehmann lovegrass, results in a positive feedback loop where initial benefits (such as providing fine fuels and increasing fire frequency) eventually result in negative impacts such as increasing the extent of less-desirable exotic grasses, lowering biodiversity, and increasing fire intensity.

Perhaps the most significant changes are projected to occur in the Mojave-Sonoran Desert Scrub ecological response unit, where trends show this system going from low to high departure after

100 years under current management. The largest change to this community type has been conversion to grassland, a direct result of land management during the 19th century to increase forage for livestock and wildlife. Historical grazing and burning has resulted in higher shrub components than would be expected under reference conditions. Exotic grasses that burn easily are becoming more common in the Sonoran Desert, resulting in more fires in these plant communities. Projections show shrub and exotic states increasing in these systems, producing contiguous fuel loads that result in higher wildfire risk. Following wet years, dense herbaceous layers can quickly fill the interspaces and bare ground, creating more fuel and increasing wildfire risk. Over time, increased fire frequency and severity can shift dominance from succulents and cacti to species with superior post-fire regeneration.

Similarity to Site Potential

Plant communities have a range of functional and structural properties that affect hydrology, nutrient cycling capability, and energy capture (Printz et al. 2014). For example, increases in shrubs and decreases in native bunch grasses can reduce infiltration and increase runoff (Jordan et al. 2007). Shifts in species composition (for example, only warm-season grasses) can negatively affect soil biota, water balance, and biological integrity. Maintaining a range of plant species with different adaptations to disturbance (for example, fire, long-term drought) will help promote ecological integrity and soil sustainability (Printz et al. 2014).

Data and Analysis Process

Similarity to site potential measures the degree of similarity between existing and natural (reference condition) plant communities for each ecological response unit. The natural plant community is a suite of species expected to occupy a site based on edaphic (soil properties) and climatic properties under natural disturbance regimes. Existing and natural communities are developed from the terrestrial ecological unit inventory, ecological classifications built from extensive field data on vegetation, climate, and soils (Jenny 1958, USDA Forest Service 1986b). Ecological response units contain several or more terrestrial ecological unit inventory map units. Similarity to site potential is calculated by species for each terrestrial ecological unit inventory map unit, using the similarity to site potential equation (USDA Forest Service 1997), and area weighted by ecological response unit to represent weighted similarity at the plan scale. The same process was repeated by species within each lifeform category (forb, shrub, graminoid, and tree) to display community level patterns that may be unequally influencing the overall site similarity or departure from similarity.

Results

Table 6 shows forb, graminoid, shrub, tree, and overall similarity to site potential at the plan scale for each ecological response unit. Ecological status is a nominal classification of similarity. Low similarity indicates highly departed species composition that may result from nonnative species invasion, altered disturbance regimes, degraded or changing environmental conditions, or other influences. Altered species composition indicates lowered ecological integrity and has a negative influence on sustainability. Forb species similarity is most dissimilar among ecological response units, followed by graminoids, trees, and shrubs. While overall site similarity is a good indicator of ecological status, lifeform similarity can inform the degree to which the community structure has departed. For example, similarity to site potential is moderate for the Sonora-Mojave Creosote-Bursage Desert Scrub ecological response unit; however, many native grasses (graminoids) are poorly represented (low similarity). Overall, similarity to site potential is low for many ecological response units due to a combination of fire suppression, historic grazing, introduced grass species, timber harvest, and drought. Generally, high elevation ecological response units are more similar than low elevation ecological response units. Higher elevations are cooler, wetter, and tend to have less inherent water stress, making them more resilient to dramatic shifts in community structure and composition.

Table 6. Similarity to site potential by lifeform at plan scale

Ecological Response Unit	Plan (overall)	Forbs	Graminoids	Shrubs	Trees
Interior Chaparral	22	6	30	47	30
Juniper Grass	26	14	45	54	51
Mixed Conifer - Frequent Fire	37	33	24	34	76
Madrean Encinal Woodland	33	42	38	60	57
Sonora-Mojave Creosote-Bursage Desert Scrub	35	53	16	62	48
Sonoran Mid-Elevation Desert Scrub	14	18	45	39	32
Sonoran Paloverde-Mixed Cactus Desert Scrub	32	26	39	66	61
Pinyon-Juniper Evergreen Shrub	21	12	28	38	39
Pinyon-Juniper Grass	28	35	44	22	32
Pinyon-Juniper Woodland	30	22	50	57	65
Ponderosa Pine - Evergreen Oak	32	30	41	34	56
Ponderosa Pine Forest	62	35	65	41	90
Semi-Desert Grassland	15	12	24	34	13
Sonora-Mohave Mixed Salt Desert Scrub	15	6	30	47	30

Red = low similarity (0 to 33 percent); yellow = moderate similarity (34 to 66 percent); green = high similarity (66 to 100 percent).

Vegetative Groundcover

Vegetative groundcover is percent combined cover of basal vegetation and litter at the plan and local scales. Groundcover provides soil stability, increases water capture, and improves moisture retention. Reduction of groundcover can lead to decreased productivity, changes in runoff timing and quantity, increased erosion, and increased sedimentation. Loss of effective vegetative groundcover adjacent to riparian areas can pose serious risks by increasing erosion, sedimentation and degrade aquatic ecosystems. Vegetation loss can also increase soil loss by wind and water erosion, especially among areas with high erosion hazard (among steep slopes). Vegetative groundcover has a strong influence on soil erosion potential.

Data and Analysis Process

Estimates of current and natural (reference condition) vegetative groundcover are available at the plan scale in the Tonto National Forest's terrestrial ecosystem survey. Total percent vegetative cover includes basal area for all plant species, as well as percent cover of litter. The change in percent vegetative groundcover is calculated for each terrestrial ecological unit, and then area-weighted to determine the average departure within each ecological response unit. Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 low, 34 to 66 moderate, and 67 to 100 high) and area weighted by ecological response unit.

Results

The majority of the ecological response units at the plan scale show low to moderate departures (table 7). The lower elevation ecological response units have low departure, however these ecological response units historically had low vegetative groundcover. Most of the moderately departed ecological response units are the woodlands and forest types. Mixed Conifer - Frequent Fire is the only ecological response unit showing a high departure in vegetative ground cover. Activities such as management-related ground disturbance, concentrated recreation, road construction and development, and historic logging and grazing have reduced vegetative groundcover in these systems. Departure is based on a nominal ranking system (0 to 33 low, 34 to 66 moderate, and 67 to 100 high) and area-weighted by ecological response unit.

Table 7. Vegetative groundcover departure from reference for each ecological response unit (ERU) at the plan scale

ERU Code	Ecological Response Unit	Reference[1]	Current[1]	Departure	Departure Category
SDS	Sonora-Mojave Mixed Salt Desert Scrub	4.7	3.4	44	Moderate
MSDS (CB)	Sonora-Mojave Creosote-Bursage Desert Scrub	7.4	6.8	11	Low
MSDS (SOS)	Sonoran Mid-Elevation Desert Scrub	10.3	12.8	1	Low
MSDS (SP)	Sonoran Paloverde-Mixed Cactus Desert Scrub	11.3	7.6	24	Low
IC	Interior Chaparral	54.0	42.0	30	Low
SDG	Semi-Desert Grassland	28	14	46	Moderate
PJO	Pinyon-Juniper Woodland	71	29	39	Moderate
JUG	Juniper Grass	49	21	44	Moderate
MEW	Madrean Encinal Woodland	46	29	53	Moderate
PJC	Pinyon-Juniper Evergreen Shrub	62	31	39	Moderate
PJG	Pinyon-Juniper Grass	36	16	49	Moderate
PPE	Ponderosa Pine - Evergreen Oak	97	60	31	Low
PPF	Ponderosa Pine Forest	119	71	37	Moderate
MCD	Mixed Conifer - Frequent Fire	132	68	80	High

1. Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent.

Coarse Woody Debris and Snag Density

Coarse woody debris is defined as dead woody material three inches and greater in diameter and is typically measured in tons per acre. Coarse woody debris (downed woody material) serves as an important ecological function. It provides wildlife habitat and contributes to the formation of soil organic matter. Coarse woody debris also helps to reduce soil erosion by shielding the soil surface from raindrop impact and interrupting rill and sheet erosion. Deficient coarse woody debris and snags can indicate an uncharacteristic lack of habitat and inadequate nutrient cycling. An overabundance may indicate underlying stress on an ecosystem (such as drought or insect outbreaks, and potentially increases wildfire severity.

Snag density is defined as the number of stems per acre by diameter classes (for example, greater than or equal to 8 inches or greater than or equal to 18 inches) at the plan scale. Snags are standing dead or partially dead trees (snag-topped), often missing many or all limbs. Like coarse woody debris, snags (standing dead trees) serve an important ecological function. Large standing snags provide key habitat for many species, such as woodpeckers that feed on insects dwelling in decomposing wood. Snags are also a source of coarse woody debris when they fall providing cover and foraging sites for small terrestrial mammals.

Data and Analysis Process

Data on existing coarse woody debris and snag densities is scarce for much of the Tonto. Ponderosa Pine Forest, Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire are the only ecological response units with stand exam (inventories) data, much of which is out of date, and the terrestrial ecosystem surveys only recently began collecting data on coarse woody debris and snags. As a result, forest inventory and analysis data was used as a surrogate for the deficiencies in coarse woody debris and snag data. Forest Inventory and Analysis Program conducts the nation’s continuous forest census, collecting, analyzing, and reporting information on the status and trends of America’s forests (forest inventory and analysis, http://www.fia.fs.fed.us). Snag data collected at the regional level was synthesized by ecological response unit and sere or seral state to develop coarse woody debris and snag density coefficients. An analysis worksheet was then developed to calculate snag densities based upon reference and current seral state proportions.

Also lacking is sufficient data on coarse woody debris and snags for the shrubland and grassland ecological response units (Mohave Sonoran Desert Scrub, Interior Chaparral, Sonora-Mohave Mixed Salt Desert Scrub, and Semi-Desert Grassland). Coarse woody debris and snag data is not typically collected within these systems, and there is not enough information on current or reference conditions to adequately assess conditions in these systems. These ecological response units are also not considered forested systems so they were not included in the forest inventory and analysis data set. Therefore, coarse woody debris and snags were not assessed for these ecological response units. Coarse woody debris and snag conditions within these ecological response units can be assessed in the future as further information becomes available for these systems.

Results

Total departure is weighted by current seral stage proportion for both coarse woody debris and snags. Because this analysis is primarily concerned with the benefits of coarse woody debris and snags to wildlife and soil health, amounts in excess of reference condition are not considered in departure and they are noted in table 8 as ND (no data).

The current distribution of coarse woody debris is well above reference conditions for most ecological response units. Coarse woody debris is well distributed and abundant in many of the mid to late seral stages, providing the full range of wildlife habitat and soil protection. However, some ecological response units with excess levels (Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, and Mixed Conifer - Frequent Fire) are at a higher risk from fire hazards (altered fire behavior, resistance to control) that can result in habitat loss. Fire exclusion, resulting in longer fire return intervals, is a contributing factor to the accumulation and excess of coarse woody debris. Areas with coarse woody debris of 40 tons per acre or greater can damage soils (heating) through increased fire intensity.

Table 8. Coarse woody debris and snags by ecological response unit

Ecological Response Unit		Coarse Woody Debris (tons/acre)			Snags per acre ≥8 inches			Snags per acre ≥18 inches		
	Seral stages	Reference	Current	Departure[1]	Reference	Current	Departure[1]	Reference	Current	Departure[1]
Pinyon-Juniper Grass (PJG)	Early	0.3	0.7	ND						
	Mid	0.2	4.0	ND						
	Late	3.0	9.8	ND						
	All	3.5	14.6	ND	5.0	5.7	18	1.0	0.9	
Juniper Grass (JUG)	Early	0.9	2.8	ND						
	Mid	0.3	2.1	ND						
	Late	1.8	3.9	ND						
	All	3.0	8.8	ND	3.0	2.7	Low	1.0	0.7	
Pinyon-Juniper Evergreen Shrub (PJC)	Early	2.4	1.5							
	Mid	0.5	11.2	ND						
	Late	0.1	11.2	ND						
	All	3.0	23.9	ND	3.0	5.6	ND	1.0	1.3	ND
Pinyon-Juniper Woodland (PJO)	Early	0.3	1.1	ND						
	Mid	0.3	5.6	ND						
	Late	3.5	10.5	ND						
	All	4.1	17.3	ND	2.0	8.4	ND	1.0	1.8	ND
Madrean Encinal Woodland (MEW)	Early	0.9	1.4	ND						
	Mid	0.8	4.7	ND						
	Late	0.5	15.2	ND						
	All	2.2	21.3	ND	4.0	5.6	ND	1.0	0.8	
Ponderosa Pine - Evergreen Oak (PPE)	Early	0.5	0.7	ND						
	Mid	0.8	5.5	ND						
	Late	2.6	30.9	ND						
	All	3.8	37.1	ND	6.0	8.7	ND	1.0	1.6	ND
Ponderosa Pine Forest (PPF)	Early	9.0	9.7	NA*						
	Mid	9.0	33.6	ND						
	Late	9.0	1.2	NA*						
	All	27.0	44.5	ND	1.1	7.8	ND	0.8	0.8	ND
Mixed Conifer - Frequent Fire (MCD)	Early	0.4	5.2	ND						
	Mid	1.8	6.0	ND						
	Late	13.0	33.6	ND						
	All	15.2	44.8	ND	9.0	19.5	ND	4.0	3.9	ND

1. Departure categories: Because this analysis is primarily concerned with the benefits of coarse woody debris and snags to wildlife, amounts in excess of reference condition are not considered in departure (ND). Low departure from reference conditions = 0 to 33 percent, green. There is no moderate or high departure for snags or coarse woody debris.

NA* = Data unavailable.

The Juniper Grass ecological response unit is the only unit that shows a low departure in both the number of snags greater than or equal to 8 inches and snags greater than or equal to 18 inches. Pinyon-Juniper Grass and Madrean Encinal Woodland ecological response units show a low departure in the number of snags greater than or equal to 18 inches. This may be because many larger trees have been harvested in the past or the species does not as frequently achieve diameters over 18 inches (as in Madrean Encinal Woodland). Large pinyon and juniper trees are also sought after by fuelwood gathers and often targeted for removal. The Ponderosa Pine Forest ecological response unit also shows low departure in the number of snags greater than or equal to 18 inches. This departure is very slight, with current condition extremely close to the reference conditions. The remaining woodland ecological response units (Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Woodland, Ponderosa Pine - Evergreen Oak, and Mixed Conifer - Frequent Fire) all show excess snags per acre in both the number of snags greater than or equal to 8 inches and the number of snags greater than or equal to 18 inches. This uncharacteristic abundance of snags per acre is especially true of smaller diameter snags, either because many larger trees have been harvested in the past or underlying stress on the ecosystem (such as drought or insect outbreaks) coupled with a longer fire return interval has resulted in a large number of smaller diameter standing dead trees.

Patch Size

A patch is a contiguous area of the same system type in the same structural state. Patch size plays a significant role in ecosystem integrity, species establishment, and wildfire behavior. Human activities (such as fire suppression and historic timber harvesting), decreased fire frequency, and increased fire severity have large impacts on patch characteristics (for example, patch size, shape, and composition) and dynamics. In fire-adapted systems, many of these activities have created uncharacteristically large patches of contiguous tree canopies, susceptible to large severe wildfires (Schoennagel 2004). Disturbances (mainly fire) create forest openings that ultimately shape patch development. Patch structure and composition depends on site conditions, species life history traits (for example, dispersal mode and shade tolerance), and characteristics of the forest opening. Patches near wetlands or lakes provide valuable seed sources for burned upland sites following catastrophic fires. Light and wind can extend 200 to 300 meters inward at patch perimeters (edge effects), producing distinct habitat at edges generally high in biodiversity relative to the interior. The shape and size of patches affect wildlife use (interior species versus edge species) and available habitat. Species may be at risk among highly fragmented habitat when there are great distances between nearby patches (many amphibians will not move between patches with distances greater than 300 meters).

Patch size influences wildfire behavior, insect and disease spread and persistence, and wildlife habitat. Larger patches mean there is less diversity in a system than there was historically. This may mean disturbances can spread more continuously, species composition is more uniform, and there is less edge habitat. In general, the reduction in heterogeneity as patch size increases lowers the resiliency of an ecosystem.

Data and Analysis Process

Midscale mapping (clipped to the Tonto National Forest boundary) was used to derive current patch size based on a set of parameters (for example, tree diameter classes) specifying woodland, forest, and non-tree patch types. The resulting geospatial layer was then intersected with the Tonto National Forest ecological response unit geospatial layer to calculate average patch size for each ecological response unit. Information on reference patch sizes for ecological response units, were obtained from interpolation, fire regime, inferences, and available literature.

Results

The scrublands (Interior Chaparral and Mohave Sonoran Desert Scrub ecological response units) make up the largest percent of the Tonto National Forest (38 percent). Patch dynamics for the Interior Chaparral ecological response unit are most affected by current long fire return intervals, a shift from high- to low-severity fires, and fire suppression. Departure is low for desert communities (Mohave Sonoran Desert Scrub) and moderate for Interior Chaparral. The Semi-Desert Grassland ecological response unit represents 12 percent of the Tonto National Forest. Small, highly departed patch sizes are the result of woody encroachment from historic livestock grazing, drought, reduced fire frequency, and fire suppression. Woodlands make up the second largest proportion of vegetation types on the Tonto National Forest (35 percent). Three out of five woodland ecological response units (60 percent) have moderate to high departure. Fire suppression and loss of surface fires through reduction or loss of understory forbs and grasses have resulted in fewer patches and increased patch sizes. For some woodland ecological response units, lowered fire severity has produced smaller patch sizes. For other woodlands, the loss of frequent low severity fires has produced large patch sizes. Two out of three forest ecological response units (66 percent) are highly departed. Large patch sizes are attributed to past even-aged management and fire exclusion.

Table 9. Average patch size (acres) at the plan scale

System Type	Ecological Response Unit	Lower Reference Condition (acres)	Upper Reference Condition (acres)	Current Patch Size	Departure % and class
Shrubland	Mojave-Sonoran Desert Scrub	4,212	8,125	4,469	0 Low
Shrubland	Interior Chaparral	930	2,120	359	61 Moderate
Grassland	Semi-Desert Grassland	1,015	1,343	47	95 High
Woodland	Pinyon-Juniper Woodland	50	400	24	52 Moderate
Woodland	Juniper Grass	0.07	0.50	30	98 High
Woodland	Madrean Encinal Woodland	0.07	50	30	0 Low
Woodland	Pinyon-Juniper Evergreen Shrub	50	200	40	20 Low
Woodland	Pinyon-Juniper Grass	0.07	1	19	95 High
Forest	Ponderosa Pine - Evergreen Oak	0.02	50	150	67 High
Forest	Ponderosa Pine Forest	0.02	0.5	363	100 High
Forest	Mixed Conifer - Frequent Fire	0.02	50	59	15 Low

Low departure = 0 to 33 percent; moderate departure = 34 to 66 percent; high departure = 67 to 100 percent

Fire Regime

Fire regime is a combination of the fire frequency and the fire severity. Fire severity is the ratio of stand replacement to non-lethal effects within a burn. Fire frequency was assessed for the national forests within the context scale and applied to the plan scale. Fire is an integral component in the function and biodiversity of many natural habitats and organisms, and these communities have adapted to withstand and even to exploit natural wildfire. More generally, fire is regarded as a natural disturbance, similar to flooding, windstorms, and landslides, that has driven the evolution of species and controls the characteristics of ecosystems. Each ecological response units has a characteristic fire regime that is integral to its ecological integrity.

Data and Analysis Process

Fire severity data was obtained from the Monitoring Trends in Burn Severity website (http://www.mtbs.gov) Reference conditions were derived from LANDFIRE 2010 and TNC 2006 as adapted in Wahlberg and others 2013. The 30-year fire history includes 1984, 1986 to 2012 obtained from Monitoring Trends in Burn Severity data. Data for years 2013 through 2014 were obtained from the Rapid Assessment of Vegetation Condition after Wildfire data (Miller et al. 2007; Rollins et al. 2006). The Rapid Assessment of Vegetation Condition after Wildfire process was used because Monitoring Trends in Burn Severity data was incomplete for 2013 and 2014. Each year's acres burned in each severity class by ecological response unit were derived by intersecting the Monitoring Trends in Burn Severity data set with the ecological response unit layer at the context scale. Fire severity was summarized by ecological response unit at the plan and context scales.

Fire frequency at the plan scale is based on Tonto National Forest fire history data from the 30-year period between 1984 and 2013. Average acreage burned per year was calculated for each ecological response unit, and the total ecological response unit acreage was divided by the average to obtain the mean fire return interval.

Results

During the years 1983 to 2013, a total of 8,262 wildfires burned 833,917 acres on the Tonto National Forest. Forestwide, the number of human-caused versus lightning-caused fires is almost evenly split. The two 'Rim' districts, Payson and Pleasant Valley, have a greater majority of lightning-caused fires. The Mesa Ranger District, with the highest recreational use and bordering the largest population centers, had the largest proportion of human-caused fires. The trend over time has been a decline in the total number of fires, although some individual large wildfires in recent years have burned many more acres than the Tonto experienced historically.

During the 30-year study period, several wildland fires had a significant and lasting effect on the landscape, altering the structure, composition, continuity, and function of the ecosystem and accelerating erosion. The Dude Fire in 1990 is often associated with a switch to wildfires exhibiting extreme behavior and unprecedented size.

Fire Frequency and Severity

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 (Agee 1993, Brown 1995). Coarse-scale definitions for natural (historical) fire regimes have been developed by Hardy et al. (2001) and Schmidt et al. (2002) and interpreted for fire and fuels management by Hann and Bunnell (2001). The five natural (historical) fire regimes 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. These five regimes are described in table 10.

Table 10. Fire regime descriptions

Fire Regime	Fire Frequency	Severity
I	0-35 year frequency	Low (surface fires most common) to mixed Less than 75% of the dominant overstory vegetation replaced
II	0-35 year frequency	High (stand replacement) Greater than 75% of the dominant overstory vegetation replaced
III	35-100+ year frequency	Mixed Less than 75% of the dominant overstory vegetation replaced
IV	35-100+ year frequency	High (stand replacement) Greater than 75% of the dominant overstory vegetation replaced
V	200+ year frequency	High (stand replacement) Greater than 75% of the dominant overstory vegetation replaced

Fire regimes are listed for each ecological response unit below (table 11) and are universal and constant for each ecosystem in reference (natural condition). Some ecological response units may display more than one regime, depending on seral state and stage of succession. Included in table 11 are comparisons of contemporary (current) average years between fires or fire return interval and the reference (historic) low end (more frequent) and high end (less frequent) intervals. Ecological response units that show departure from the range of reference fire return interval will suffer changes their relationship with fire as an ecological function.

Table 11. Fire return intervals by ecological response unit

Ecological Response Unit	Fire Regime	Forest Mean Return Interval	Reference Return Interval (low)	Reference Return Interval (high)
Mojave-Sonoran Desert Scrub (MSDS)	None / III	126	35	100+
Semi-Desert Grassland (SDG)	II	210	0	35
Interior Chaparral (IC)	IV (II)	128	35 (0)	100+ (35)
Pinyon-Juniper Grass (PJG)	I	215	0	35
Juniper Grass (JUG)	I	96	0	35
Pinyon-Juniper Evergreen Shrub (PJC)	III / IV	272	35	100+
Pinyon-Juniper Woodland (PJO)	V (III)	201	35	200+
Madrean Encinal Woodland (MEW)	I (III)	170	0 (35)	35 (100+)
Ponderosa Pine - Evergreen Oak (PPE)	I (III)	115	0 (35)	35 (100+)
Ponderosa Pine Forest (PPF)	I	84	0	35
Mixed Conifer - Frequent Fire (MCD)	I (III)	58	0 (35)	35 (100+)

Table 12 displays the fire regimes by ecological response unit and the percent of acres burned in each ecological response unit by severity class. We would expect ecological response units within their respective fire regime to experience varying amounts of fire severity. In this specific case, fire severity refers to the effect of fire on the dominant vegetation type. As an example, the

Ponderosa Pine Forest ecological response unit would be expected to experience 75 percent or more non-lethal fire with some minor patches of mixed severity (fire regime I). However, 37 percent of acres burned by contemporary fires in the Ponderosa Pine Forest ecological response unit have experienced mixed to stand-replacing severity. Overall, all ecological response units with a reference fire regime of I are experiencing more high-severity fires than would be expected historically. This change in fire severity is influenced by the lengthening of the fire interval, increased fuel loading, and more complex fuel structure. Ecological response units with less frequent and higher severity fire regimes (III, IV, V), such as Interior Chaparral and Pinyon-Juniper Woodlands, are burning with severities more similar to those expected historically.

Table 12. Fire severity by ecological response unit (ERU)

Ecological Response Unit	Fire Regime	Severity Class	Percent of Burned Acres
Mojave-Sonoran Desert Scrub (MSDS)	None / III	Non-Lethal Mixed Severity Stand-Replacing	75 % 20 % 5 %
Semi-Desert Grassland (SDG)	II	Non-Lethal Mixed Severity Stand-Replacing	72 % 22 % 6 %
Interior Chaparral (IC)	IV (II)	Non-Lethal Mixed Severity Stand-Replacing	51 % 33 % 16 %
Pinyon-Juniper Grass (PJG)	I	Non-Lethal Mixed Severity Stand-Replacing	42 % 29 % 29 %
Juniper Grass (JUG)	I	Non-Lethal Mixed Severity Stand-Replacing	74 % 21 % 5 %
Pinyon-Juniper Evergreen Shrub (PJC)	III / IV	Non-Lethal Mixed Severity Stand-Replacing	57 % 25 % 18 %
Pinyon-Juniper Woodland (PJO)	V (III)	Non-Lethal Mixed Severity Stand-Replacing	68 % 27 % 5 %
Madrean Encinal Woodland (MEW)	I (III)	Non-Lethal Mixed Severity Stand-Replacing	57 % 38 % 5 %
Ponderosa Pine - Evergreen Oak (PPE)	I (III)	Non-Lethal Mixed Severity Stand-Replacing	57 % 27 % 16 %
Ponderosa Pine Forest (PPF)	I	Non-Lethal Mixed Severity Stand-Replacing	63 % 21 % 16 %
Mixed Conifer - Frequent Fire (MDC)	I (III)	Non-Lethal Mixed Severity Stand-Replacing	50 % 26 % 24 %

Fire severity and fire interval have changed for these ecological response units spread across the mid portions of the Lower Verde subbasin, Tonto Creek subbasin, and Upper Salt subbasin, and to a lesser extent, part of the Agua Fria subbasin. Any ecological response units that showed a significant amount of acres in the fire regime III, as these did, are at higher risk.

The pine, pine-oak, and the dry mixed-conifer ecological response units (Ponderosa Pine Forest, Ponderosa Pine - Evergreen Oak, Mixed Conifer - Frequent Fire) are located below the Mogollon Rim in the northern portions of the Lower Verde subbasin, Tonto Creek subbasin, and Upper Salt subbasin. There are additional coniferous forests, to a lesser extent, in the southern part of the Upper Salt subbasin. This expression of departure indicates these ecological response units are at increasing risk.

Some of the ecological response units on the Tonto National Forest would not have fires burning at reference conditions in all three severity classes or even two of the classes. But because of departure, all the ecological response units on the Tonto have fires in the 30-year history burning at all three severity classes.

Fire Regime Condition Class

Fire regime condition class combines successional state departure and fire regime departure into a single metric. Fire regime condition class is an important tool for measuring the effectiveness of efforts to maintain sustainable landscapes (National Interagency Fuels, Fire, and Vegetation Technology Transfer 2010). Fire regime condition class ratings describe a level of departure from native ecosystems as they existed prior to Euro-American settlement:

- Fire regime condition class I – Fire regimes are within the natural range of variation and risk of losing key ecosystem components is low. Vegetation attributes (composition and structure) are intact and functioning (departure less than 33 percent).
- Fire regime condition class II – Fire regimes have been moderately altered. Risk of losing key ecosystem components is moderate. Fire frequencies may have departed by one or more return intervals (either increased or decreased), potentially resulting in moderate changes in fire and vegetation attributes (33 to 66 percent departed).
- Fire regime condition class III – Fire regimes have been substantially altered. Risk of losing key ecosystem components is high. Fire frequencies may have departed by multiple return intervals, potentially resulting in dramatic changes in fire size, fire intensity, and fire severity as well as landscape patterns. Vegetation attributes have been substantially altered (more than 66 percent departed).

Data and Analysis Process

Fire regime condition class was calculated at the local scale by averaging seral state proportion departure and fire regime departure. Characteristic fire regime was defined as the average of historic range of variation reported for each ecological response unit below. Local scale ratings were area weighted for each ecological response unit to determine a percentage by class at the plan scale. Ecological response units with higher proportions in fire regime condition class II or III are at higher risk of loss of ecosystem integrity as a result of uncharacteristic disturbance.

Fire regime condition class is a classification of the amount of departure from the historical natural fire regime (Hann and Bunnell 2001). Coarse-scale fire regime condition class includes three condition classes for each fire regime. The departure in each class results from changes to one (or more) of the following ecological components:

- Vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern)
- Fuel composition
- Fire frequency
- Severity and pattern
- Other associated disturbances (for example, insect and disease mortality, grazing, and drought)

The three classes are based on low (fire regime condition class I), moderate (fire regime condition class II), and high (fire regime condition class III) departure, as described below in table 13. The greater the departure from natural conditions a forested site is, the greater probability of dramatic disturbance from agents such as insect, disease, fire, and flood. Condition classes are used as a risk factor in forest health analysis. Low departure is considered to be within the natural (historical) range of variation, while moderate and high departures are outside.

Table 13. Fire regime condition class descriptions

Fire Regime Condition Class	Description	Potential Risks
Condition Class I	Within the natural (historical) range of variation of vegetation characteristics; fuel composition; fire frequency severity and pattern; and other associated disturbances	Fire behavior, effects, and other associated disturbances are similar to those that occurred prior to fire exclusion (suppression) and other types of management that do not mimic the natural fire regime and associated vegetation and fuel characteristics. Composition and structure of vegetation and fuels are similar to the natural (historical) regime Risk of loss of key ecosystem components (for example, native species, large trees, and soil) is low.
Condition Class II	Moderate departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Fire behavior, effects, and other associated disturbances are moderately departed (more or less severe). Composition and structure of vegetation and fuel are moderately altered. Risk of loss of key ecosystem components is moderate; Uncharacteristic conditions range from low to moderate.
Condition Class III	High departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Fire behavior, effects, and other associated disturbances are highly departed (more or less severe). Composition and structure of vegetation and fuel are highly altered Uncharacteristic conditions range from moderate to high; Risk of loss of key ecosystem components is high.

Characteristic vegetation and fuel conditions are considered to be those that occurred within the natural (historical) fire regime. Uncharacteristic conditions are considered to be those that did not occur within the natural (historical) fire regime, such as invasive species (weeds, insects, and diseases), "high graded" forest composition and structure (large trees removed in a frequent surface fire regime would be atypical or unnatural), or repeated annual grazing that maintains grassy fuels across relatively large areas at levels that will not carry a surface fire. Determination of amount of departure is based on comparison of a composite measure of fire regime attributes (vegetation characteristics; fuel composition; fire frequency, severity, and pattern) to the central tendency of the natural (historical) fire regime.

Results

The fire regime would remain constant for each of the different vegetation types (ecological response units) but the condition class would move closer to a condition class 1, where vegetation composition, structure, and fuels are similar to those of the natural regime and do not predispose the system to risk of loss of key ecosystem components. Condition class 1 for the pine types, Ponderosa Pine Forest and Ponderosa Pine - Evergreen Oak (both fire regime I), would resemble an open forest maintained by frequent, low-severity fires. Condition class 1 for the woodland types, Pinyon-Juniper Woodland and Madrean Encinal Woodland (both fire regime III), would resemble a mosaic of open forest to mid-seral maintained by mixed-severity fires recurring generally every 35 to 100 years.

Table 14. Fire regime condition class by percent in each ecological response unit

Ecological Response Unit (ERU)	ERU Acreage	% ERU on Tonto National Forest	Fire Regime Condition Class 1	Fire Regime Condition Class 2	Fire Regime Condition Class 3
Mixed Conifer - Frequent Fire (MDC)	51,990	2 %	23 %	29 %	48 %
Madrean Encinal Woodland (MEW)	93,769	3 %	0 %	100 %	0 %
Sonoran Palo Verde-Mixed Cactus Desert Scrub (MSDS-SP)	624,610	21 %	44 %	0 %	56 %
Pinyon-Juniper Evergreen Shrub (PJC)	402,035	13 %	21 %	79 %	0 %
Pinyon-Juniper Grass (PJG)	80,699	3 %	0 %	100 %	0 %
Pinyon-Juniper Woodland (PJO)	55,963	2 %	20 %	80 %	0 %
Ponderosa Pine - Evergreen Oak (PPE)	217,838	7 %	0 %	54 %	46 %
Ponderosa Pine Forest (PPF)	37,471	1 %	0 %	49 %	51 %
Juniper Grass (JUG)	416,445	14 %	0 %	100 %	0 %
Semi-Desert Grassland (SDG)	346,707	12 %	0 %	52 %	48 %
Interior Chaparral (IC)	294,352	10 %	22 %	78 %	0 %
Totals	2,621,880	88 %			

Madrean Encinal Woodland and Juniper Grass ecological response units are the only ones showing all their acres in fire regime condition class II. This indicates that, although there are many acres that are removed from reference conditions, they could move towards condition class I with subsequent management or moderate disturbance such as the reintroduction of fire in those ecosystems.

Terrestrial Ecosystem Stressors

All ecosystems are adapted to a range of natural disturbances, such as fire, insect outbreaks, and drought. Large changes in vegetation structure, composition and ecological processes can occur under natural disturbances but when systems are resilient recovery is generally rapid (Rapport and Whitford 1999). Anthropogenic stressors (land use, introduction of exotic species, overharvesting, management) has reduced resiliency among many ecosystems over the past century, impairing and or reducing biodiversity and ecological integrity. Therefore even system drivers, such as fire or insects, can become stressors among highly impaired ecosystems.

Insect and Disease

Insects and pathogens are natural disturbance agents, however they can also function as stressors when the resiliency of a system is compromised (for example, high stand density, prolonged drought), allowing pathogens and insect outbreaks to reach lethal levels. Under natural conditions, activity by these agents should always be expected, though extent and severity of damage will vary.

A century-long record of insect and disease activity on the Tonto National Forest provides some information on which species impact it, how often to expect outbreaks of insects and transitory pathogens, and how much damage to expect from insects and diseases. Due to the episodic nature of insect outbreaks, damage must be evaluated over an extended period before designating any shorter period as unusual. Overall, insect activity has increased on Tonto National Forest since the late 1990s, and the acreage affected in the ponderosa pine forest and pinyon-juniper woodlands is much greater than during any earlier period in the historic record. It has not been determined if differences between the 1950s and contemporary drought is due entirely to changes in forest structure and composition or if different temperature regimes also play a role (Breshears et al. 2005).

It would not be prudent to expect insect activity over the next 10 to 20 years to be similar to the 1970s and 1980s. Contemporary trends have enough differences from historic trends to anticipate altered ecosystem processes. The co-occurrence of competitive vegetation densities, drought, and warm climate has increased forest vulnerability to herbivorous insects, especially bark beetles. There is potential for catastrophic insect outbreaks to continue in the pine and mixed-conifer forests, but it is difficult to characterize the risks in a temporal framework of 10 to 20 years. There is more uncertainty regarding future insect outbreaks than the past record indicates. The Tonto National Forest is in a period of significant climatic and ecological change and should expect additional large-scale insect disturbances, though the details of those events cannot be predicted.

In the pinyon-juniper woodland communities, the extent and severity of the die-off, higher levels of mortality in the larger, reproductive trees, and preferential mortality of pinyon versus juniper, is causing a vegetation shift. Pinyon-juniper woodlands are becoming dominated by juniper, a species typical of lower elevation and more arid conditions (Allen 2007; Mueller et al. 2005). Pinyon needle scale is known to increase susceptibility to bark beetle attacks, as observed during multiple outbreaks in 2009 and 2010. Severe infections of pinyon dwarf mistletoe can increase susceptibility to bark beetle infections. Within the Pinyon-Juniper Woodland ecological response unit, insects and pathogens are likely a more causal natural disturbance agent than fire.

Due to the high variability of species compositions in mixed conifer forests, multiple insect pests occur, and the relative risk of damaging outbreaks by these species varies with availability of host species. Douglas fire tussock moth is present in the Pinal and Sierra Ancha Mountains. It preferentially attacks white fir and Douglas fir and can cause total defoliation of trees with mortality of up to 40 to 100 percent, which can trigger subsequent Douglas fir beetle outbreaks. Though acreage affected recently by Douglas-fir beetle is small with respect to the extensive mortality in ponderosa pine and pinyon-juniper, Douglas-fir beetle has the potential to cause considerable damage under the right conditions. Resource impacts can be considerable because of the insect's preference for the largest trees, which are valued for numerous reasons. Large trees also disproportionately contribute to Douglas-fir beetle population growth, as Douglas-fir beetle prefers large trees and large amounts of beetle brood are produced in large, infested trees.

Fir engraver attacks white fir trees stressed by drought, defoliation, root disease, and competition (Ferrell et al. 1994). Although earlier records do not indicate this insect caused significant damage on the Tonto National Forest, white fir prevalence has been increasing on the Tonto due to fire exclusion and so have its pests. Root disease is probably increasing due to the increase in susceptible non-resinous conifer species, though because of the difficulties associated with identifying this pathogen, impacts are generally underestimated. Spruce aphid, an exotic insect that became established on Tonto National Forest between the 1990s and 2000s, can cause 25 to 40 percent mortality of severely damaged trees (many already infested with dwarf mistletoe). Aspen are declining across the Southwest. They are at risk for increasing western tent caterpillar defoliation (among other species) and activity of bark beetle species (less risk).

In ponderosa pine-dominated forests, the affected area is much larger than the affected pinyon-juniper area. These forests remain dominated by ponderosa pine, though the demographic distributions may have changed. Bark beetles (*Ips* and *Dendroctonus* species) caused an unprecedented severe outbreak in the 2000s. They occurred in over 63 percent of Ponderosa Pine Forest and Ponderosa Pine - Evergreen Oak ecological response units and caused 24 to 25 percent mortality, which was close to 100 percent of trees in some stands. There is an increasing trend of bark beetles in dense stands of smaller-diameter trees or drought- or mistletoe-stressed trees. Dwarf mistletoe infection is widespread and increasing. A survey completed 30 years ago found infection in 19 percent of commercial acres; more recent surveys found it infecting 47 percent. This increase is caused by a change in fire regimes and management practices and is a high risk because heavy mistletoe infections often precede chronic bark beetle attacks. Ponderosa pine needleminer was not recorded on Tonto National Forest prior to 1999 and doesn't currently pose a severe risk, but it is capable of large outbreaks in extensive areas of host trees and potential mortality. Tip moths and shoot borers can damage the main stem of young trees and retard or deform growth in fire and bark beetle recovery areas, which has the potential to become a risk into the future.

Several of these changes in disturbance regimes appear to be responses to changes in forest structure and composition that resulted from fire exclusion and past management practices: *Ips* species responding to an abundance of dense, small-diameter ponderosa pine, at least to some extent; pinyon *Ips* responding to increased extent and density of pinyon; and spread and intensification of dwarf mistletoe in ponderosa pine. Drought is clearly a factor as well, but the specific role a warming climate plays is not clear. Other than continued spread and intensification of dwarf mistletoe populations, and subsequent increased tree and forest vulnerability to bark beetles, pathogen response to climate change, insect outbreaks, and altered forest composition and fire regimes is less predictable than insect population responses. Additionally, there is uncertainty regarding the potential introduction and effects of exotic insect and pathogen species, as well as the effects of exotic invasive plants on forest disturbance regimes, including insect and pathogen disturbance agents. Even in the face of uncertainty regarding future climate and insect and pathogen activity, general management recommendations for reducing susceptibility and vulnerability to insects and diseases remain the same: improve tree vigor and maintain forest health by maintaining natural species, size, and age class distributions.

Invasive Plant Species

Defined under the executive order establishing the National Invasive Species Council, an invasive species is “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Exec. No. 13112, 1999). Invasive species are not necessarily the same as noxious weeds (although many are invasive). Noxious weeds are species designated by Federal, State, or County government as harmful to humans, agriculture crops, ecosystems, and livestock (Sheley et al. 1999). In this section of the assessment, we describe invasive species capable of altering native species composition, structure and ecosystem functioning. Noxious weeds and their effects on human health, livestock, fish and wildlife, recreation, and economics are discussed in the appropriate sections of the assessment. The establishment and spread of invasive species can increase wildfire risk (for example, production of fine fuels from exotic grasses), affect soil erosion and chemistry, alter nutrient cycling, and displace other species. Generally these effects are greatest when disturbance is high and site conditions are poor.

Data and Analysis Process

A categorized list of invasive nonnative plants for the State of Arizona was developed by the Arizona Wildlands Invasive Plant Working Group. The group is comprised of representatives from Federal, State, and local organizations: U.S. Department of Agriculture, U.S. Geological Survey, The Nature Conservancy, the National Park Service, Northern Arizona University, University of Arizona, and others (Warner et al. 2003). Species ranking (high, medium, low) are evaluated based on ecological impacts (fire occurrence, erosion, hydrological regimes, nutrient cycling), invasiveness (role of human and natural disturbance in establishment), ecological distribution (the extent of invasion for a given ecological type) and current ecological amplitude (the number of ecological types invaded). Caution should be taken when interpreting invasive species risk to ecosystems. Arizona Wildlands Invasive Plant Working Group rankings describe invasive species overall risk to ecosystems across species range; however, effects on ecosystems can vary between sites (or example, high-elevation versus low-elevation sites). Invasive species, distribution (mapped and inferred) and risk to ecosystems are described for each ecological response unit on the Tonto National Forest.

Results

The Tonto National Forest has a relatively low abundance of invasive species compared to other western forests. Threats to ecosystems from invasive plant species are generally more severe among low- to mid-elevation sites (D'Antonio et al. 2004; Klinger et al. 2006). Out of the known invasive species on the Tonto National Forest, invasive grasses are the most abundant and widespread. Cool-season, annual brome grasses pose significant threats to the Arizona-upland subdivision of the Sonoran Desert by increasing fires and displacing native species not adapted to fire (D'Antonio and Vitousek 1992). The Cave Creek Complex Fire in 2005, fueled by red brome, killed a significant proportion (estimated 20 percent) of the cacti and succulent vegetation of the Sonoran Desert scrub in Arizona (Tonto National Forest Invasives EA 2012). Other exotic grasses, such as fountain grass and buffelgrass, are fire adapted and when growing in an ecosystem not adapted to fire, such as the Sonoran Desert, are capable of disrupting fire regimes and displacing native grass species. In systems where fire is part of the ecology (desert grasslands and chaparral), fountain grass is less of an ecological threat (Van Devender 2004 in Fountain Grass Assessment). Invasive forb species (for example, knapweed and thistles) represent a fairly small proportion of inventoried weeds; they are mainly found on recently disturbed soils along roads and highways. They have the potential to displace native species and increase soil erosion, especially among sites once occupied by native sod-forming bunch grasses. Additionally, many invasive forbs (Dalmatian toadflax, Scotch and bull thistles) are not typically used by native wildlife.

Most of the weeds inventoried on the Tonto are near highways or main roads for three reasons: 1) much of the survey effort has been conducted for road construction or maintenance projects (there are more remote infestations, but they are harder to find and may not be near projects that require survey); 2) weeds tend to initially establish in disturbed areas such as road shoulders and barrow ditches; and 3) roads and motorized trails are known to be effective vectors for transporting invasive plant propagules (vegetative and seed sources). Recreational vehicles (all-terrain vehicles, bicycles, and motorcycles), road use, construction, and maintenance (road-grading equipment) directly affect soil compaction and erosion which directly affect the establishment and spread of invasive species.

The invasive plant species found on the Tonto National Forest are described below. The Arizona Wildlands Invasive Plant Working Group ranking (high, medium, low) is evaluated based on ecological impacts (fire occurrence, erosion, hydrological regimes, nutrient cycling), invasiveness (role of human and natural disturbance in establishment), ecological distribution (the extent of invasion for a given ecological type) and current ecological amplitude (the number of ecological types invaded).

The Tonto National Forest categorizes invasive plant species as class A, B, or C weeds. Class A weeds are limited in distribution in Arizona, and the management goal is eradication. Class B weeds are of limited distribution in Arizona, and the management goal is to contain spread and eliminate populations. Class C weeds have spread beyond the capability to eradicate; the management goal is to reduce population sizes if possible.

- Asian mustard (*Brassica tournefortii*): 3,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is moderate. The Tonto National Forest category is class C. This species is widespread on the Tonto. It progresses in waves following extremely wet years. Biomass accumulates at roadsides increasing wildfire risk to adjacent deserts.

- Buffelgrass (*Pennisetum ciliare*): 6,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class B. This species has limited distribution; it is mostly restricted to roadsides. Potential fuel loads of buffelgrass may lead to increased wildfire risk.
- Bull thistle (*Cirsium vulgare*): 20,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is low. The Tonto National Forest category is class C. This species has limited distribution; it is primarily found at higher moist sites. Bull thistle does not compete well with established native vegetation. It requires disturbance for seeds to land and germinate.
- Canada thistle (*Cirsium arvense*): 8 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is moderate. The Tonto National Forest category is class A. This species has limited distribution; it is found near Canyon Creek in the Pleasant Valley Ranger District. Canada thistle competes with native vegetation and depletes soil nutrients and moisture.
- Dalmatian toadflax (*Linaria dalmatica*): 35 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is moderate. The Tonto National Forest category is class A. The distribution is limited; it is found near the Payson Ranger District. With Dalmation toadflax, there is intense competition for soil water by mature, well-developed tap roots and extensive lateral roots.
- Diffuse knapweed (*Centaurea diffusa*): 250 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is moderate. The Tonto National Forest category is class B. This species has limited distribution; there are small infestations in the Pleasant Valley Ranger District. Impacts of diffuse knapweed are increased soil erosion.
- Fountain grass (*Pennisetum setaceum*): 7,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class B. This species is widespread on the Tonto; it is found on all ranger districts. Fountain grass increases fuel loads which increases intensity and spread of fires.
- Jointed goatgrass (*Aegilops cylindrical*): 10 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is low. The Tonto National Forest category is class B. This species has limited distribution; recent populations were discovered along Highway 87. If established, jointed goatgrass may produce sufficient litter to carry surface fires.
- Malta starthistle (*Centaurea melitensis*): 65,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is moderate. The Tonto National Forest category is class C. This species is widespread at low elevations. Malta starthistle increases soil moisture loss and erosion.
- Red brome (*Bromus rubens*): 150,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class C. This species is widespread at low to mid elevations. Red brome alters fire frequency, intensity, and spread. It depletes soil moisture and nutrients.
- Russian knapweed (*Acroptilon repens*): 2 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class A. This species has limited distribution; it is found near Payson and Gordon Canyon. Russian knapweed alters soil chemistry and soil moisture and may increase fire return intervals.

- Scotch thistle (*Onopordum acanthium*): 50 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is low. The Tonto National Forest category is class B. This species has limited distribution; it is found at mid to high elevations, riparian areas. Scotch thistle impacts to ecosystems are not clear. It invades areas where native, sod-forming species have been displaced.
- Sweet resinbush (*Euryops subcarnosus*): 27 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class A. This species has limited distribution; it is found in the Tonto Basin. Sweet resinbush increases soil erosion. There are few localized populations with active control efforts.
- Yellow starthistle (*Centaurea solstitialis*): 8,000 acres on the Tonto National Forest. The Arizona Wildlands Invasive Plant Working Group ranking is high. The Tonto National Forest category is class B. This species has limited distribution, mainly at higher elevations. Yellow starthistle increases in soil moisture loss and erosion.

Invasive species acreage, distribution, and known impacts on the Tonto National Forest are summarized from the "Environmental Assessment for Integrated Treatment of Noxious or Invasive Plants" (USDA Forest Service 2012). Other sources used to assess invasive species impacts were obtained from the Arizona Wildlands Invasive Plant Working Group through the Southwest Exotic Plant Information Clearinghouse (Warner et al. 2003).

Terrestrial Vegetation

Sonora-Mojave Mixed Salt Desert Scrub (SDS)

Elevation: 1,900 – 3,200 feet

Table 15. Distribution (acres and percent) at the context, plan, and local scales for Sonora-Mojave Mixed Salt Desert Scrub

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
319,354	21,095	0	2,387	12,091	6,616	0
3%	1%	0	0.3%	1.9%	0.9%	0

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (the national forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 16. Terrestrial ecosystem niche, Sonora-Mojave Mixed Salt Desert Scrub

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
6.6%	-0.55	Low

Photo 1. Sonora-Mojave Mixed Salt Desert Scrub

Regionally, this vegetation type is rare on national forest lands. It occurs in the low sun mild climate gradient and includes extensive open-canopied shrublands of typically saline basins in the Mojave and Sonoran Deserts. Stands often occur around playas. Substrates are generally fine-textured, saline soils. Vegetation is typically composed of one or more saltbush species such as *Atriplex canescence* or *Atriplex polycarpa* along with other species of *Atriplex*. Species of *Allenrolfea*, *Salicornia*, *Suaeda*, or other halophytic plants are often present to codominant. Graminoid species may include *Sporobolus airoides* or *Distichlis spicata* at varying densities. Making up 1 percent of the Tonto National Forest, the Sonora-Mojave Mixed Salt Desert Scrub ecological response unit is poorly represented. Most acres are located in the Tonto Basin zone and Upper Salt zone with minor occurrences in the Lower Verde zone. Modeling was not done for this ecological response unit as it has too few acres on the Tonto National Forest to accurately assess trends.

Reference Conditions

Desert shrublands have been largely influenced by climatic factors, varying soil properties, and, to a lesser extent, fire (Paysen et al. 2000). Desert communities largely evolved without fire as an ecological process; therefore, many species are not fire adapted. Prior to Euro-American settlement, fires did occur, largely from lightning and Native Americans; however, most deserts did not burn except during unusual circumstances. The ability for desert plant species to recover from fire depends on genetic variation, resprouting ability, seed characteristics, and delayed mortality (Paysen et al. 2000). Historically salt scrub communities lacked contiguous fuel sources, greatly limiting fires (Paysen et al. 2000; Wahlberg et al. 2013).

Trees are generally absent from the Sonora-Mojave Mixed Salt Desert Scrub. Shrubs in these ecosystems can act as important nurse plants, affect (positive or negative) the establishment of certain species, and influence community dynamics. The mosaic of shrubs produces distinctive microhabitats (under canopy and interspaces) that have significant influences on seed distribution, germination, and survival of other species (McAuliffe 1988). Increased germination can occur from windblown material accumulating under the canopy of shrubs. Lowered temperatures under shrub canopies also greatly increase germination and survival of other plants.

Current Conditions

Historically, this vegetation type reached its dominance along the lower Gila and Salt Rivers in south-central Arizona (Creutzburg 2012). Today, much of this vegetation has been converted to agriculture. Exotic grasses that burn easily are becoming more common in the Sonoran Desert, resulting in more fires in these plant communities (Brooks and Pyke 2001). Exotic species, including filaree (*Erodium cicutarium*) and prickly lettuce (*Latuca serriola*), and native species, such as *Spaeralcea*, contribute to fine fuels that are easily ignited in this vegetation type. While historic conditions would have limited the risk of fires in these systems, today many have the ability to support fires from the accumulation of exotics (annual grasses such as red brome) that provide contiguous fine fuels (Bunting et al. 2002; Pellant and Reichert 1984). Risk is especially high following wet years where annual exotics reach significant fuel loads (Sparks et al. 1990).

The late development open state B (graminoids and shrubs make up 10 to 25 percent in cover) is slightly overrepresented, and the early development state A (fewer shrubs than the late development state) is somewhat underrepresented on the Tonto National Forest (plan scale). Exotic states C and D have the highest potential to carry fine fuels. Currently, about 1 percent of exotics are present at the plan scale. The Lower Verde zone has moderate departure (highest), while all other local zones and the plan scale have low departure. This is most influenced by an increase in the percent of acres in the early development state (increase from 15 to 55.5 percent). Also, this zone has the highest proportion of exotics (C, D).

The reduced representation of seral state B at the Lower Verde zone is attributed to past and current ground disturbance. While fire data is unavailable for this ecological response unit, the establishment of fine fuels from exotics are likely introducing uncharacteristic fire, further influencing departure. Degraded site conditions are also likely influencing shifts in vegetation composition and structure, evident by the low similarity to site potential. Soil conditions in these communities are the second most departed (82 percent) among the desert ecological response units (reference “Soils” section). Lowered site productivity has significant influences on hydrological function, plant growth, and soil stability. Dominant long-lived species, such as fourwing saltbrush (*Atriplex canescens*), are underrepresented for this ecological response unit. Highly disturbed areas with highly compacted and degraded soils can significantly limit plant growth, specifically among long-lived dominants, and shift species dominance to more disturbance-adapted species (Charley and Cowling 1968). Loss of shrubs greatly impacts other species establishment and survival and impacts soil nutrient levels (that is, lowers site productivity) as many shrubs concentrate organic debris below the canopy.

Future Trend

Future trends have not been modeled for this ecological response unit but vulnerability to climate change is high with moderate uncertainty of effects (reference the "Climate Change" section). Projections of increased aridity in the Southwest (Seager et al. 2007) are likely to have negative impacts on certain species, such as shallow-rooted species (grasses and forbs) that are dependent on precipitation-derived moisture. The loss of such species can have significant influences on site productivity, soil health, structure, and ecological integrity. Also, when site conditions deteriorate, opportunities for exotics to establish increase. Regionally, very few of these communities are operating under historic fire regimes. With increasing fire frequencies and the long recovery periods needed for many typical salt scrub species (for example, *Atriplex*), reduction in native shrubs and increase in disturbed areas will become more common. While the opportunity for the Tonto National Forest to influence the sustainability of this ecological response unit at the landscape level is low, this ecological response unit is rare in the context scale and the Tonto can contribute to ecosystem maintenance by minimizing activities that degrade soils and vegetative ground cover (specifically at the Agua Fria zone). Also, given the proximity of this vegetation type to urban areas, increasing pressures from urban development are likely to have negative impacts to this ecological response unit at the broader landscape.

Sonora-Mojave Mixed Salt Desert Scrub (SDS)

Overstory Structure and Composition

Seral State Proportion

				Current and Projected Conditions on the Tonto NF[1]						
State	**Description**	**Reference**	**Context Scale[2]**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[3] (100 years)**
A	Early Development	15%	NA	----	55.5	1.5	1.9	----	7	NA
B	Late Development Open	85%	NA	----	42.0	98.1	97.6	----	92	NA
C, D	Exotics	0%	NA	----	2.5	0.5	0.5	----	1	NA
		Departure[4]:	NA	----				----		NA

1. Dashed lines indicate the ecological response unit is not sufficiently distributed at scale for analysis.
2. NA = Data unavailable
3. Too few acres (0.76 percent of plan area) to model ecological response unit.
4. Departure: L = low (0 to 33 percent); M = moderate (34 to 66 percent); and H = high (67 to 100 percent). See “Seral State Proportion” section (page 24) for explanation of departure calculation.

Average Patch Size: Not assessed for this ecological response unit.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Graminoids: Three-awn grasses (*Aristida* spp.) have increased at some locations.

Shrubs and trees: Typical shrubs such as fourwing saltbrush (*Atriplex canescens*) have decreased in abundance, while blue palo verde (*Parkinsonia florida*) has increased at other areas.

Lifeform	**Forbs[1]**	**Graminoids[2]**	**Shrubs**	**Trees**	**All lifeforms (overall)**
Similarity to site potential (plan scale)	Low (28%)	Low (17%)	Moderate (38%)	Low (12%)	Low (15)
Species present/potential species	14/20	7/7	24/30	2/2	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 4.7 percent

Current = 3.4 percent

Departure = Moderate (44)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags analysis does not apply to this ecological response unit.

Ecosystem Drivers and Stressors

Fire: Historical and current fire is thought to be minimal to absent for this ecological response unit.

Insect and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: buffelgrass (*Pennisetum ciliare*), fountain grass (*Pennisetum setaceum*), red brome (*Bromus rubens*).
- Moderate: Asian mustard (*Brassica tournefortii*), Malta starthistle (*Centaurea melitensis*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Seventy-two acres of noxious weeds have been mapped in this ecological response unit.

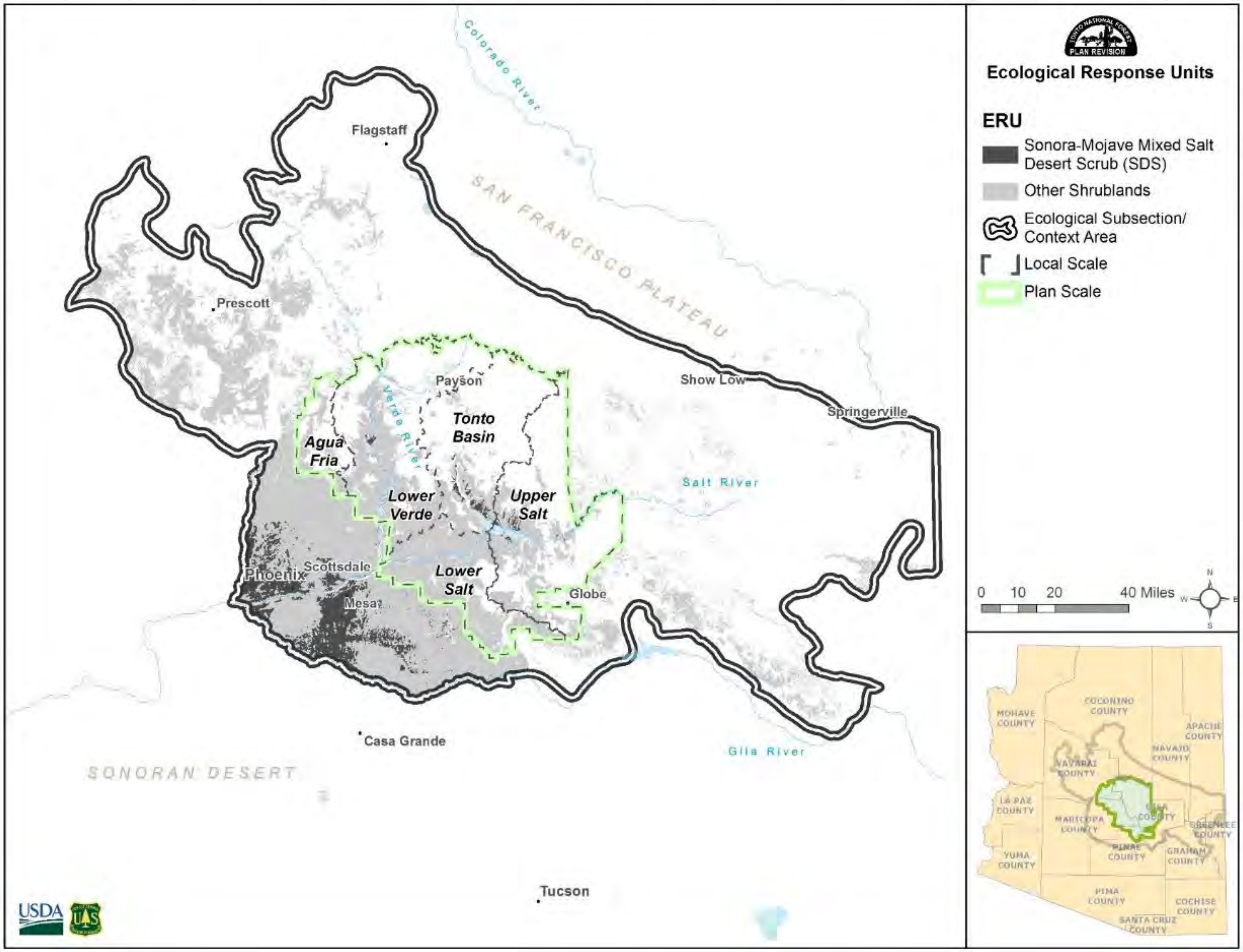


Figure 7. Sonora-Mojave Mixed Salt Desert Scrub ecological response unit

Mojave-Sonoran Desert Scrub (MSDS)

Given the large extent of Mojave-Sonoran Desert Scrub and range of features (topography, soil attributes, and precipitation) on the landscape, there are three provisional subclasses: Sonora-Mojave Creosote-Bursage Desert Scrub, Sonoran Paloverde-Mixed Cactus Scrub, and Sonoran Mid-Elevation Desert Scrub. The Sonora-Mojave Creosote-Bursage ecological response unit is treated together with the Sonoran Paloverde-Mixed Cactus Scrub ecological response unit (MSDS-SP) because there are slight differences between these two systems and future models will combine these two provisional classes. The Sonoran Mid-Elevation Desert Scrub provisional subclass (MSDS-SOS) was not modeled because the appropriate model is not yet available (currently being developed).

A general vegetation description is given for Mojave-Sonoran Desert Scrub followed by reference conditions applicable to both provisional subclasses. Further vegetation description and conditions, current and future, are provided for both provisional subclasses Sonoran Paloverde-Mixed Cactus Scrub and Sonoran Mid-Elevation Desert Scrub.

Photo 2. Mojave-Sonoran Desert Scrub

Found primarily below 4,000 feet in elevation, the Mojave-Sonoran Desert Scrub ecological response unit is most common on the Tonto and Coronado National Forests. Areas in this vegetation type vary from barren rocky substrates (less than 1 percent plant cover) to lands with deep, well-developed soils supporting dense succulents, desert grasses, perennial shrubs, and some herbaceous ephemerals that emerge during infrequent wet periods, then quickly mature, flower, and produce seed as drought conditions return. Where winters are mild, a sparse emergent tree layer of saguaro cactus (*Carnegia gigantea*), palo verde (*Parkinsonia microphylla*), and ironwood (*Olneya tesota*) can be found among alluvial fans with dominant creosote (*Larrea* tridentata) and bursage (*Ambrosia sp.*) shrubs. At higher elevations and on steep mountain slopes, creosote is replaced by up to 50 percent cover of small trees and shrubs such as fairyduster (*Callicandra eriophylla*), brittlebush (*Encelia farinosa*) and jojoba (*Simmondsia chinensis*) (Wahlberg et al. 2013). Ephemeral watercourses support dense vegetation such as wolfberry (*Lycium sp.*) and catclaw (*Acacia greggii*). Covering 808,098 acres, this ecological response unit makes up a significant proportion (27 percent) of the Tonto (figure 8), covering more area than any other ecological response unit. Additionally, the acreage on the Tonto represents a large proportion of the Mojave-Sonoran Desert Scrub acreage at the context scale (38 percent).

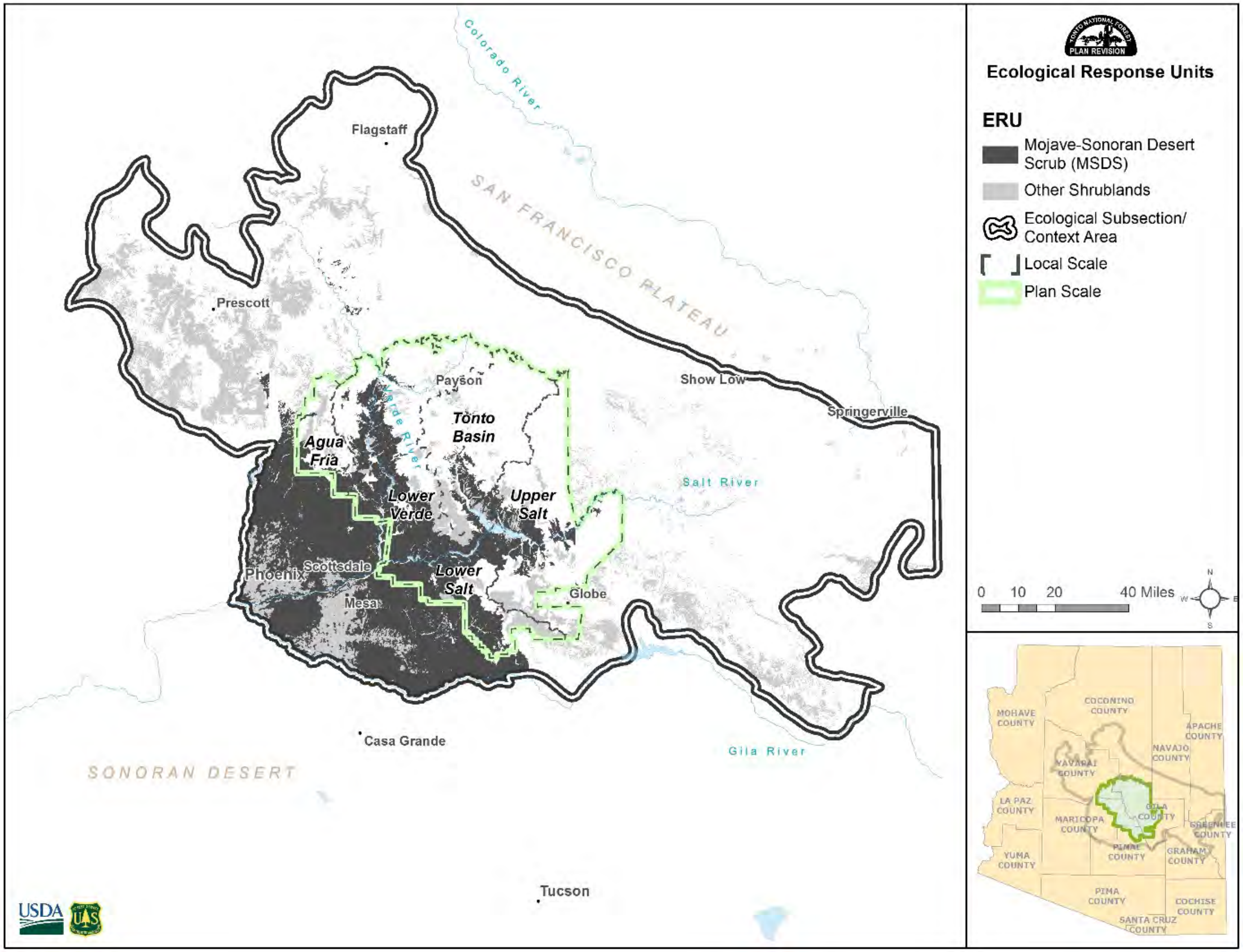


Figure 8. Mojave-Sonoran Desert Scrub ecological response unit

Reference Conditions

Desert shrublands have been largely influenced by climatic factors, varying soil properties, and, to a lesser, extent fire (Paysen et al. 2000). Desert communities largely evolved without fire as an ecological process, therefore many species are not fire adapted (for example, succulents). Prior to Euro-American settlement fires did occur, largely from lightning and Native Americans, however most deserts did not burn except during unusual circumstances (Paysen et al. 2000). The ability for desert plant species to recover from fire depends on genetic variation, resprouting ability, seed characteristics, and delayed mortality (Paysen et al. 2000). The herbaceous layer in these communities can reach high densities during wet years, producing high fuel loads capable of supporting major fires. The bimodal rainfall (winter and summer) in the Sonoran Desert allows for a greater structural diversity in vegetation than neighboring deserts such as the Great Basin, Mohave, and Chihuahuan Deserts (Brown 1994).

Drought is the primary natural disturbance process associated with deserts. Desert plants employ many unique strategies, such as effective water storage to cope with temporary and extended periods of drought, many persisting for months to years with very little to no rain. Many succulent plant species have extensive lateral roots that enable them to capitalize on very little soil moisture following brief precipitation events. Drought dormancy (for example, dropping leaves), allows plants to avoid desiccation during unfavorable conditions. While many succulents respond to brief precipitation events, desert shrubs and trees generally require greater amounts of precipitation to reach deeper soil levels where the root zone is located. Some desert trees, such as mesquite (*Prosopis*), obtain a significant proportion of water from groundwater sources (phreatophytes). Desert annuals are more common in arid environments and make up a significant proportion of the Sonoran Desert. The quick germination and flowering strategies for these plants allow them to complete their life cycles quickly during favorable conditions and lie dormant during unfavorable conditions. Strong associations exist between many cactus and perennial species. Several species benefit by establishing under canopies where herbivory is reduced, resulting in increased survival rates (McAuliffe 1988). Desert trees also have strong influences on community structure and species establishment; for example, the establishment of the iconic Saguaro cactus is strongly tied to frugivorous birds that disperse seeds beneath the canopy of desert trees (Hutto et al. 1986).

Sonoran Palo Verde-Mixed Cactus Desert Scrub (MSDS-SP) and Sonora-Mojave-Bursage Desert Scrub (MSDS-SOS)

Elevation: 1,300 – 5,800 feet

Table 17. Sonoran Palo Verde-Mixed Cactus Desert Scrub (MSDS-SP) and Sonora-Mojave-Bursage Desert Scrub (MSDS-SOS) distribution (acres and percent) at the context, plan, and local scales

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
2,001,286	656,632	25,525	213,571	39,195	94,064	284,279
16.0%	24.0%	15.0%	27.7%	6.3%	12.3%	65.3%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest’s opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the “Terrestrial Ecosystem Spatial Niche” section for complete analysis.

Table 18. Terrestrial ecosystem niche, Sonoran Palo Verde-Mixed Cactus Desert Scrub and Sonora-Mojave-Bursage Desert Scrub

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
96.4%	0.62	High

This community type has a diverse assemblage of vegetation including the iconic Saguaro cactus (*Carnegiea gigantea*), paloverde (*Parkinsonia microphylla*), ironwood (*Olneya tesota*), and tall shrubs such as catclaw (*Acacia greggii*), wolfberry (*Lycium sp*.), jojoba (*Simmondsia chinensis*), teddy-bear cactus (*Cylindropuntia bigelovii*) (Creutzburg 2012). Brittlebush (*Encelia farinosa*) is generally more common than creosote (*Larrea tridentata*) on warm slopes. Most of the vegetation occurs at mid to high elevations, on slopes greater than 20 percent and at areas with less than 10 inches of precipitation (Creutzburg 2012). Vegetation types at bajadas/foothills include tall paloverde (*Parkinsonia microphylla*) and ironwood trees, creosotebush, triangle-leaf bursage (*Ambrosia deltoidea*) and succulents including the Sauguaro cactus. These communities at bajadas are found at alluvial fans and pediments of less than 20 percent slope eclipsed by frost at higher elevations (Creutzburg 2012). At lower elevations, bursage (*Ambrosia dumosa*), big galleta grass (*Pleuraphis rigida*) and creosote bush (*Larrea tridentate*) is commonly found among sandy flats and dunes. This community type is the most abundant on the Tonto National Forest (24 percent) and is more or less just as common at the context scale. On the Tonto most acres are in the Lower Salt zone (65 percent).

Current Conditions

The largest change to this community type in the Southwest has been conversion to grassland, a direct result of land management during the 19th century to increase forage for livestock and wildlife. Historical overgrazing and burning has resulted in higher shrub components than would be expected under reference conditions. Exotic grasses that burn easily are becoming more common in the Sonoran Desert, resulting in more fires in these plant communities (Brooks and Pyke 2001). Animal burrowing and plant root architecture play key roles in regulating soil-plant health, growth, and community establishment among *Larrea-Ambrosia* communities. Ground disturbance can lead to soil compaction and loss (as little as 5-10 cm at soil surface), hinder the recovery of plants, potentially eliminate long-lived dominates such as creosote and shift dominance to short-lived disturbance adapted species (including natives and exotics). At some sites depending on the level of disturbance, effects to these plant communities can last up to 40 years (Prose et al. 1987). Past land management along with exotic grass invasion has supplied many areas with a contiguous fuel source producing larger more frequent fires. The cacti and succulent component is most negatively affected following fires, generally shifting dominance to the grass component. For example, the Cave Creek Complex Fire in 2005, fueled by red brome, killed a significant proportion (estimated 20 percent) of the cacti and succulent vegetation of the Sonoran Desert scrub in Arizona (Tonto National Forest Invasives EA 2012).

Current conditions are similar between the Tonto National Forest and context scale, with more acres in the later seral stages (open, cacti tree, and shrub cover up to 25 percent) and fewer acres in the mid-seral stages (10 to 30 percent shrub and tree cover). While overall departure is low at both the plan and context scales, departure is highest at the Lower Salt and Agua Fria zones. Both the Agua Fria and Tonto Basin have the highest proportion of exotic seral states at 0.9 and 0.7 percent, respectively. Also, a significant proportion of this ecological response unit is classified in fire regime condition class III (55 percent), indicating high departure in fire regime. Fire behavior is largely affected by fire severity, fire frequency, species composition, structure, and presence of exotics. Invasive species encroachment along with altered vegetation structure (for example, increased shrub densities) are influencing uncharacteristic fire in these ecosystems.

Soil condition for these communities are the most departed compared to all other ecological response units on the Tonto (reference soils section). Impaired soils have a direct effect on site productivity, which is captured in the low similarity to site potential. Grass species composition and abundance is the most dissimilar to site potential. Many grasses play important roles in maintaining ecological integrity. For example, native bunch forming grasses stabilize blowing sand and reduce erosion. Exotics were only detected in the Agua Fria zone. Similarity to site potential also shows a reduction of tree species. Tree species composition and abundance is important for this ecological response unit, as many serve as nurse plants (such as Ironwood, mesquite, and palo verde) that have strong influences on the establishment and survivorship of other species (Suzan et al. 1996). Fungi and soil crusts play key roles in ecological functioning and significantly reduce erosion potential from wind and water. Repeated disturbance can significantly reduce or eliminate biological crusts that can negatively affect seedling germination, plant growth, and nutrient availability, especially among sparse community types in arid environments (Belnap et al. 2001). The loss of biological crusts may have also contributed to the lowered site productivity and impaired soils.

Future Trend

It is common to have naturally high fuel loads in desert shrublands, with some areas reaching levels as high as 2,000 pounds per acre (Paysen et al. 2000). Historically, when fires did occur, negative impacts were minimal because naturally occurring fuel loads were discontinuous patches that limited the spread of fires. Projections (state-and-transition modeling) show a reduction in all states but most pronounced in the late development (cacti, shrub, and tree) component and an increase in exotic states. Projections are likely over-estimating the influence of exotics as invasion potential is not equally distributed in this system. The current model is more closely tied to the invasion potential at mountainous areas at warm slopes (Sonora Paloverde-Mixed Cactus Desert Scrub – Mountains provisional subclass) where buffelgrass invasion is more likely than it is at the lower bajadas. Buffelgrass is more of a threat than red brome to montane paloverde cacti communities along southern exposures. Red brome has a much higher invasion potential at lowland bajadas than at mountainous areas. Currently the Mojave-Sonoran Desert Scrub model is being refined to better capture these differences.

As shrub and exotics increase in these systems, discontinuous fuel loads shift to contiguous ones and result in higher wildfire risk. Following wet years, dense herbaceous layers can quickly fill the interspaces and bare ground, creating more fuel and increasing wildfire risk. Over time, increased fire frequency and severity can shift dominance from succulents and cacti to species with superior post-fire regeneration. Annual red brome (*Bromus rubens*) and perennial buffelgrass (*Pennisetum ciliare*) can rapidly expand following wet years (D'Antonio and Vitousek 1992); however, fires in red brome are relatively mild compared to those in buffelgrass (Creutzburg 2012). Regionally, buffelgrass is more common at lower elevation Sonoran deserts (primarily restricted by frost); however, new cultivars may extend the range of this grass increasing risk at higher elevations (Tonto National Forest Invasives EA 2012).

Recovery from fire is slow among desert shrublands and depends on factors such as topography, species composition, and amount of precipitation following fire. Changing precipitation regimes in the Southwest (Seager et al. 2012), along with higher fuel loads, are likely to have negative impacts to the ecological integrity of these systems. While typical flora of these communities are species well adapted to very low soil moisture levels (e.g., creosote), projections of increased aridity in the Southwest (Seager et al. 2007) are likely to have negative impacts on certain species, such as shallow-rooted species, those that dependent on precipitation-derived moisture. This could result in a lowered abundance of certain native grass and forb species. Regionally, fragmentation from development and recreation pose the highest risks to these community types. Areas of high recreational impact (such as off-highway vehicle use) will require future monitoring to insure disturbances are minimized to reduce soil erosion and loss, spread of invasive species and loss of native vegetation – specifically at areas with bare ground and ongoing ground disturbance activities.

Sonoran Palo Verde-Mixed Cactus Desert Scrub (MSDS-SP) and Sonora-Mojave-Bursage Desert Scrub (MSDS-SOS)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[1] (100 years)**
A	Sparsely vegetated, recently burned, herb dominated, tree and shrub cover < 10%	5	1.1	0.6	1.0	0.1	0.3	1.8	1.1	4.4
D, G	Mid-Seral / 10 – 30% Shrub & Tree Cover	20	14.8	30.8	17.1	23.1	19.7	8.1	14.6	7.1
B, C	High Seral (open)	75	83.9	67.8	81.4	76.2	79.5	89.6	83.8	17.7
E, F, H, I, J	Exotics	0	0.2	0.9	0.5	0.7	0.5	0.4	0.5	70.8
		Departure[2]:								

1. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See “Seral State Proportion” section (page 24) for more information.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 4,212 to 8,125 acres. Current patch size = 4,469 acres. Departure is within the natural range of variation.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Overall, native buckwheat (*Eriogonum spp.*) has increased in abundance.

Graminoids: Three-awn grasses (*Aristida spp.*) have increased in abundance at some locations, while muhly grasses such as *Muhlenbergia polycaulis* have decreased in abundance at other locations.

Shrubs and trees: Foothill palo verde (*Parkinsonia microphylla*) has decreased in abundance, while blue palo verde (*Parkinsonia florida*) has increased in abundance. Brittlebush (*Encelia farinosa*), and prickly pear cactus have increased in abundance while triangle bursage (*Ambrosia deltoidea*) has decrease in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (26%)	Moderate (39%)	Moderate (66%)	Moderate (61%)	**Low (32)**
Species present/potential Species	61/101	23/34	60/84	6/7	

1. Forbs include all herbaceous flowering plants.
2 Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 11.3 percent

Current = 7.6 percent

Departure = Low (11)

Plant basal area and litter estimates are combined, resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags analysis does not apply to this ecological response unit.

Ecosystem Drivers and Stressors

Fire: Return interval and severity values are taken from Mojave Sonoran Desert Scrub (including all subclasses) analysis.

Fire reference conditions: While the historic role of fire is thought to be minimal to absent in desert ecosystems, some areas may have experienced mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III).

Fire current conditions: Fire return interval = 250 years

Fire severity: Non-lethal = 75 percent. Mixed-severity = 20 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 44 percent. Class II = 0 percent. Class III = 56 percent

Insects and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: buffelgrass (*Pennisetum ciliare*), fountain grass (*Pennisetum setaceum*), red brome (*Bromus rubens*).
- Moderate: Asian mustard (*Brassica tournefortii*), Malta starthistle (*Centaurea melitensis*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Five hundred and eighty-five acres of noxious weeds have been mapped in this ecological response unit.

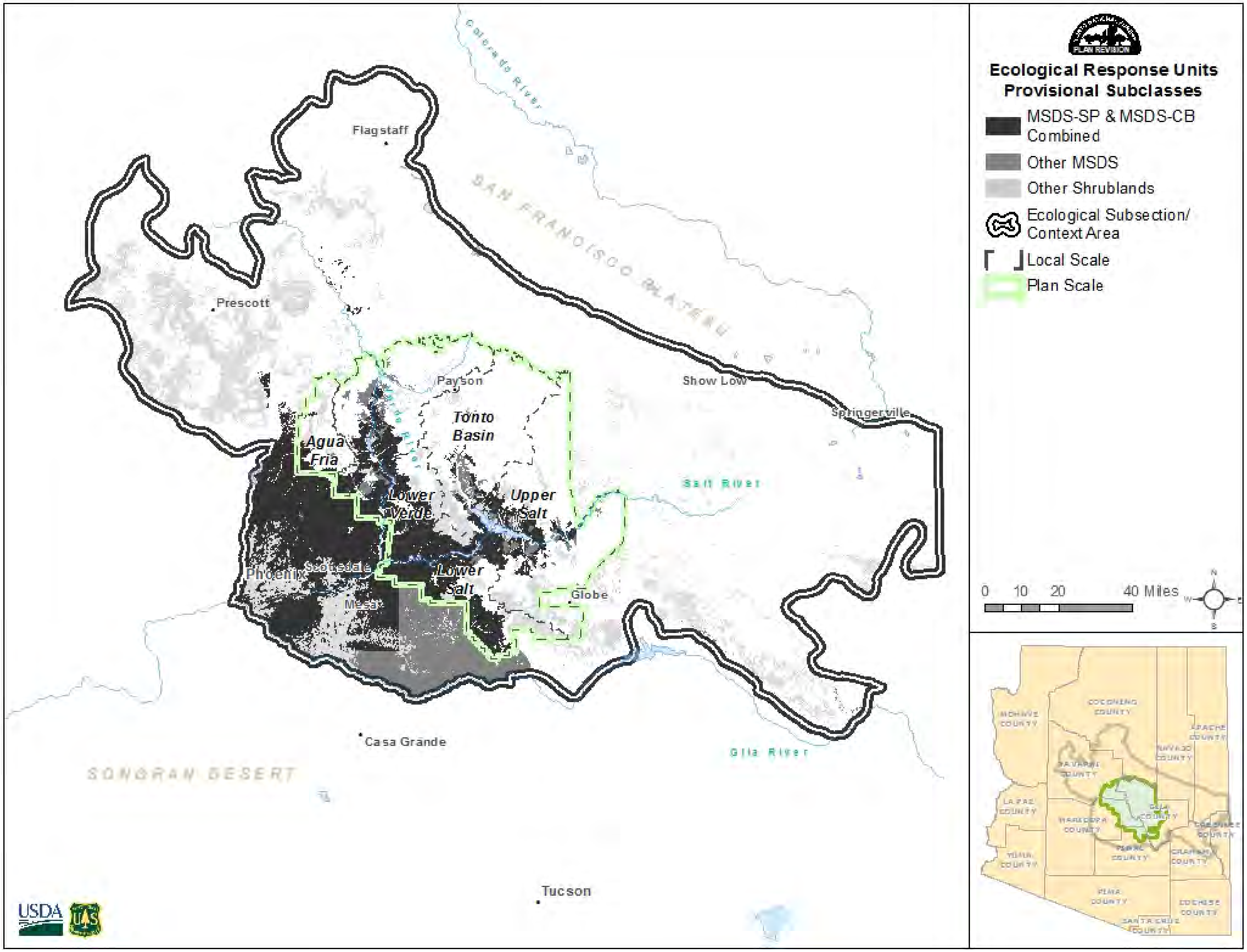


Figure 9. Sonoran Palo Verde-Mixed Cactus Desert Scrub and Sonora-Mojave Creosote Bursage Desert Scrub ecological response units

Sonoran Mid-Elevation Desert Scrub (MSDS SOS)

Elevation: 1,700 – 5,100 feet

Table 19. Distribution (acres and percent) at the context, plan, and local scales for Sonoran Mid-Elevation Desert Scrub

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
114,344	113,557	1,054	56,256	24,972	26,403	4,873
1%	4%	0.6%	7.3%	4.0%	3.5%	1.1%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The national forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 20. Terrestrial ecosystem niche, Sonoran Mid-Elevation Desert Scrub

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
99.3%	0.63	High

This ecological response unit is at higher elevations than frost-sensitive paloverde-mixed cacti scrub ecological response unit and generally below dense chaparral vegetation (Creutzburg 2012). Typical vegetation includes buckwheat (*Eriogonum fasiculatum*), jojoba (*Simmondsia chinensis*) and creosote (*Larrea tridentata*). In central Arizona, crucifixion thorn (*Canotia holacantha*) is a hallmark species (Creutzburg 2012). Most of this ecological response unit subclass occurs at mid to high elevations. While the Sonoran Mid-Elevation Desert Scrub ecological response unit only makes up 4 percent of the Tonto National Forest, almost all of the context acres are located on the Tonto (99.3 percent). On the Tonto, most acres are spread across the Lower Verde, Tonto Basin, and Upper Salt zones.

Current Conditions

The establishment exotic annuals (red brome, Mediterranean grass, and others) have introduced uncharacteristic fires in these communities (Creutzburg 2012). Currently departure is moderate at both the plan and context scale. On the Tonto, departure is significantly higher at the Lower Salt zone. The trend in departure among seral state proportions are similar at all scales: the mid development state (B) is highly overrepresented while the early (A) and the late development states (C) are poorly represented. The exception to this is overrepresentation of the early sparsely vegetated state at the Agua Fria zone. All local zones have exotic states. Past livestock grazing may have influenced the lowered late development of shrubs and trees at some sites. Jojoba does have high forage value to livestock and wildlife. While jojoba is fairly resistant to moderate browsing, heavy browsing was documented to reduce shrub cover in southern Arizona (Roundy and Dobrenz 1989).

Exotics are also likely influencing wildfire and current departure. While many desert plants are not fire-adapted, jojoba sprouts from the root crown following fires; however, seeds may not survive severe fires, and establishment is greatly influenced by the availability of nurse plants (Matthews 1994). Fire can convert this vegetation type to shrub habitat dominated by turpentine bush, *Ericameria laricifolia* (Creutzburg 2012), and similarity to site potential does show a general overrepresentation of turpentine bush.

Future Trend

Future trends have not been modeled for this ecological response unit, however the Tonto National Forest has a unique influence on the sustainability of this ecological response unit at the broader landscape as 99.3 percent of the context acres are located on the Tonto. This ecological response unit is present in all local zones. Most acres are in the Lower Verde zone; however, departure is highest at the Lower Salt zone. The presence of exotics in all zones pose significant threats to native species. Exotic annuals, including red brome and Sahara mustard, contribute to fine fuels that destroy native vegetation and convert areas to uncharacteristic shrub communities (which appears to have already occurred at sites). Many desert communities have important soil crusts that regulate soil biota, plant health, and growth, and studies have shown fewer exotic annuals establish when these crusts are intact (Kaltenecher et al. 1999). A fair amount of soils in these communities are impaired to unsatisfactory (collectively at 47 percent). This may exacerbate exotic establishment and spread and wildfire risk. The loss of late-development shrub and tree species can have negative impacts to other native species establishment and persistence given the high association between desert plants in these communities (that is, nurse plants).

Sonoran Mid-Elevation Desert Scrub (MSDS SOS)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[1] (100 years)**
A	Sparsely vegetated, recently burned, herb dominated, tree and shrub cover < 10%	5	3.9	16.4	5.7	2.6	1.9	0.0	4.0	N/A
B	Mid development, shrub dominated (< 2 meters height), cover greater than 10%	20	72.9	54.0	76.6	59.4	76.6	91.5	73.2	N/A
C	Late development, shrub (> 2 meters height) and tree cover greater than 10%	75	23.0	28.7	17.2	37.6	21.0	8.1	22.3	N/A
D, E	Exotics	0	0.5	1.0	0.6	0.5	0.5	0.4	0.2	N/A
		Departure[2]:	54 (M)	46 (M)	58 (M)	40 (M)	57 (M)	72 (H)	53 (M)	N/A

1. Currently models are unavailable for Sonoran Mid-Elevation Desert Scrub.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 4,212 to 8,125 acres. Current patch size = 4,469 acres. Departure is within the natural range of variation.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Overall, native buckwheat (*Eriogonum spp.*) and broom snakeweed (*Gutierrezia sarothrae*) have increased in abundance.

Shrubs and trees: Turpentine bush (*Ericameria laricifolia*), fairy duster (*Calliandra spp.*) and velvet mesquite have all increased in abundance.

Lifeform	**Forbs[1]**	**Graminoids[2]**	**Shrubs**	**Trees**	**All lifeforms (overall)**
Similarity to site potential (plan scale)	Low (18%)	Moderate (45%)	Moderate (39%)	Low (32%)	**Low (14)**
Species present/potential Species	18/62	10/21	34/45	5/6	

1. Forbs include all herbaceous flowering plants.
2 Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 10.3 percent

Current = 12.8 percent

Departure = Low (1)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags analysis does not apply to this ecological response unit.

Ecosystem Drivers and Stressors

Fire: Return interval and severity values taken from Mojave Sonoran Desert Scrub (including all subclasses) analysis. Fire regime condition class values are taken from the Sonoran Paloverde-Mixed Cactus Desert Scrub analysis

Fire reference conditions: While the historic role of fire is thought to be minimal to absent in desert ecosystems, some areas may have experienced mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35-100+ years (fire regime III).

Fire current conditions: Fire return interval = 250 years

Fire severity: Non-lethal = 75 percent. Mixed-severity = 20 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 44 percent. Class II = 0 percent. Class III = 56 percent

Insects and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: buffelgrass (*Pennisetum ciliare*), fountain grass (*Pennisetum setaceum*), red brome (*Bromus rubens*).
- Moderate: Asian mustard (*Brassica tournefortii*), Malta starthistle (*Centaurea melitensis*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Seventy-two acres of noxious weeds have been mapped in this ecological response unit.

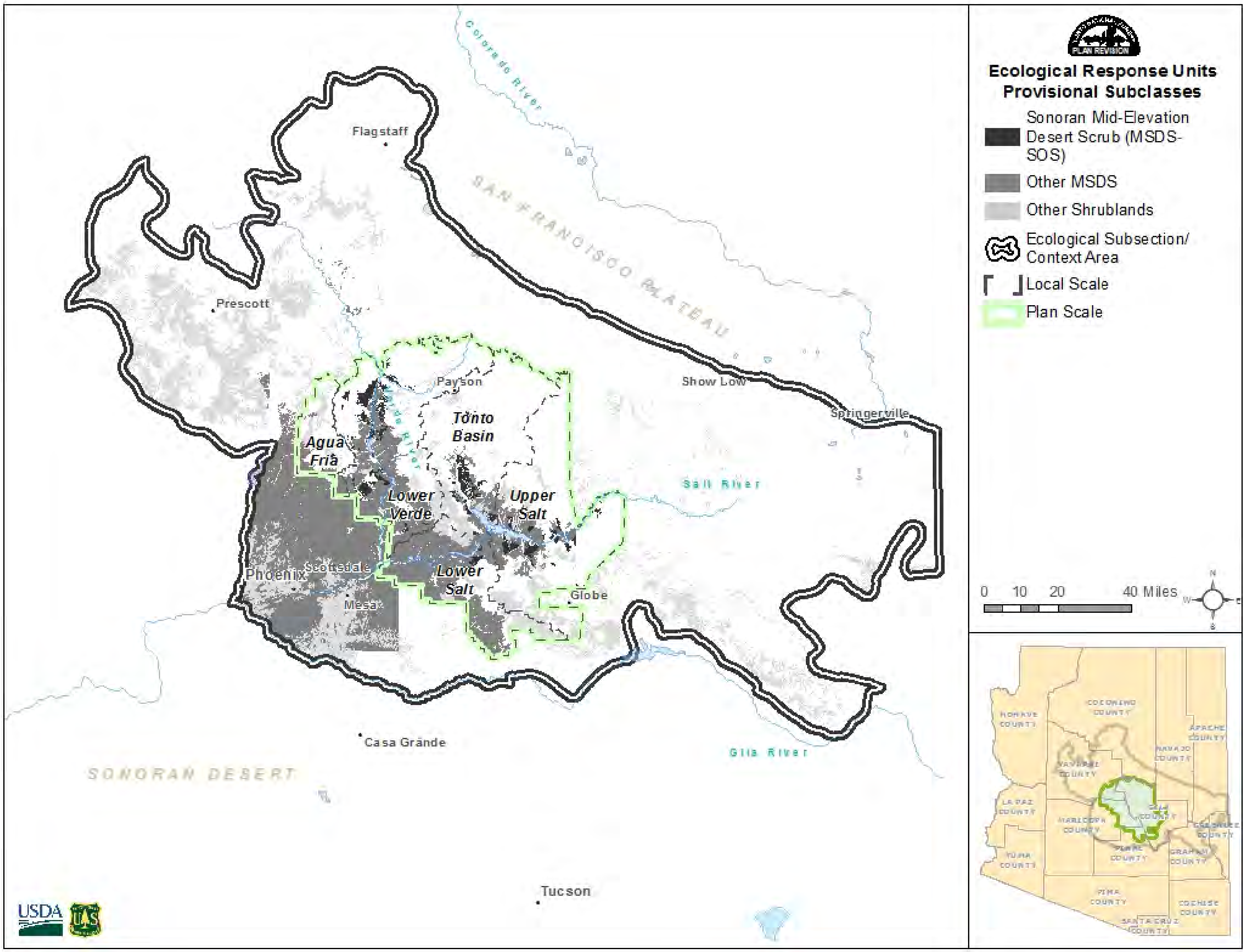


Figure 10. Sonoran Mid-Elevation Desert Scrub ecological response unit

Interior Chaparral (IC)

Elevation: 2,300 – 7,800 feet

Table 21. Distribution (acres and percent) at the context, plan, and local scales for Interior Chaparral

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
1,300,963	290,771	29,135	50,473	45,699	93,036	72,427
11%	11%	17.2%	6.5%	7.4%	12.2%	16.6%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 22. Terrestrial ecosystem niche, Interior Chaparral

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
22.4%	-0.01	Low

Photo 3. Interior Chaparral

Transitioning from low-elevation deserts, Interior Chaparral consists of woody evergreen shrubs at low slopes and mountain foothills. Typical shrub species include Manzanita (*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.) (Wahlberg et al. 2013). Sparse tree cover is typical of this ecological response unit; therefore, some pinyon, juniper, or ponderosa pine associations with sparse tree cover are grouped with this ecological response unit. The Interior Chaparral ecological response unit makes up 11 percent of the Tonto National Forest and is equally represented at the national forest and the broader landscape. On the Tonto, the acres are more or less equally distributed across local zones.

Reference Conditions

Shrubs in these communities are not as easily ignited as grasses; however, if conditions are favorable, they can burn readily (Paysen et al. 2000). The historic fire regime for interior chaparral consisted of high-severity fires with fire return intervals of 50 to 100 years, occasionally covering large expanses (Cable 1975; Pase and Brown 1982). Species composition and site factors can have strong influences on fire behavior. Fine and heavy fuel loads are largely determined by the size class of many chaparral species, such as manzanita. With the exception of dense stands of chamise, the sparse canopy of many woody chaparral species on their own lack sufficient fuels to spread fires. Dry windy conditions are generally required to maintain and carry crown fires. Among fully developed stands, ladder fuels are practically non-existent as there is generally little to no herbaceous understory (Paysen et al. 2000). However, at sites where an understory is present fires are greatly enhanced, depending on fuel moisture content.

It is suggested that dead fuel production in chaparral generally increases among older stands, but age is not the only factor (Paysen and Cohen 1990). The rapid response to fire is largely attributed to local site conditions, species post-fire regeneration (sprouting) and the germination of seed reserves in the area. These factors result in a mosaic of age classes across the landscape (Huebner and Vankat 2003). While chaparral structure is relatively stable, species composition appears to be more dynamic; entire shifts in species dominance can occur following disturbance events (Schussman 2006)

Current Conditions

Interior Chaparral has been less affected by human disturbance (including fire) and management than other woodland and forest types. This is largely attributed to the relatively broad fire return interval chaparral is adapted to, the fast recovery in these systems, and resistance to grazing pressures (density of shrubs and steep slopes). Also past fire suppression has been generally offset by increased human-caused ignitions (Paysen et al. 2000). Most significant changes have been an overall increase in shrub densities (Huebner et al. 1999) and reduction of herbs. Huebner at al. (1999) documented little change form historic conditions among chaparral in central Arizona.

Similar to trends regionally in Arizona, interior chaparral is lowly departed from reference conditions at the plan and context scale. However, departure is slightly higher at the plan scale with moderate departure among the Lower Salt, Tonto Basin, and Agua Fria zones and low departure among the Lower Verde and Upper Salt zones. The largest change is the increase in mid development states (B) where vegetation structure is open, with 10 to 30 percent cover and a slight reduction in the mature closed state (C, D). The reduction of mature closed states is most influenced by the suppression of fires that would have historically reached larger extents. Instead smaller fires have produced openings, creating much smaller average patch sizes (359 acres) compared to reference conditions (930 to 2,120 acres).

Past attempts to convert chaparral to grassland occurred regionally in Arizona and on the Tonto National Forest but largely failed. Management focused on maintaining shrubs in sprout stage, altering composition, and reseeding (Cable 1975). Goats were also used in attempts to reduce undesired woody vegetation; however, these activities were noted to negatively impact highly important and palatable forage (mountain mahogany and Wright's silktassel) for wildlife (Knipe 1983). The loss of these important forage species lowers forage diversity, induces nutritional stress to livestock and wildlife, and impacts nutrient cycling within chaparral (Severson and DeBano 1991). Forb species composition is the most dissimilar to reference conditions and overall similarity to site potential is low. While there have been overall increases in desert ceanothus, Wright's silktassel (*Garrya wrightii*) is poorly represented in this community type (similarity to site potential). The risk of invasive species within Interior chaparral are low and potential risks come from fires spreading into chaparral from neighboring vegetation types with increased fire loads (Tonto National Forest Invasives EA 2012).

Future Trend

Projections (Vegetation Dynamics Development Tool modeling) show conditions trending towards reference conditions where 98 percent is in the mature closed state (C, D), 2 percent in the mid development open state (B) and 1 percent in the grass, forb and shrub state (A). This is not surprising given the fast recovery time and resilience in these communities. Also the change in management to more holistic approaches (wildlife habitat, maintaining slope stability and watersheds, sustainable rangeland practices) are allowing these communities to naturally trend towards reference conditions over time. Interior chaparral is about equally common in and outside (context) the Tonto but only 22.4 percent of the context acres are in the Tonto National Forest. For these reasons, along with the overall low current and projected departure, the opportunity for the Tonto to influence the sustainability of this ecological response unit at the broader landscape is low.

Interior Chaparral (IC)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	Description	Reference	Context Scale	1: Agua Fria	2: Lower Verde	3: Tonto Basin	4: Upper Salt	5: Lower Salt	Plan Scale	Projection[1] (100 years)
A	Grass/Forb/Shrub	2	6	24	18	14	2	7	10	1
B	Mid development 10-30% shrub cover (open)	5	12	23	20	34	15	42	26	2
C, D	Mature (closed)	93	83	53	62	52	82	51	63	98
		Departure[2]:	10 (L)	40 (M)	31 (L)	41 (M)	11 (L)	42 (M)	30 (L)	5 (L)

1. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale), see "Seral State Proportion" section for more information.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See "Seral State Proportion" section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 930 to 2,120 acres. Current patch size = 359 acres. Departure = Moderate, smaller.

Understory Structure and Composition

Percent similarity to site potential by lifeform at plan scale

Forbs: Native buckwheat (*Eriogonum spp.*) has decreased in abundance, while shrubby deervetch (*Lotus rigidus*) has increased in abundance.

Graminoids: Blue grama and hairy grama grasses (*Bouteloua gracilis* and *Bouteloua curtipendula*) have increased in abundance.

Shrubs and trees: Overall, pointleaf manzanita (*Arcostaphylos pungens*), alligator juniper (*Juniperus deppeana*), Emory oak (*Quercus emoryi*) and desert ceanothus have increased in abundance, while Wright's silktassel (*Garrya wrightii*) has decreased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (6%)	Low (30%)	Moderate (47%)	Low (30%)	**Low (22)**
Species present/potential species	4/29	10/23	26/44	8/8	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 54 percent

Current = 42 percent

Departure = Low (30)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags analysis does not apply to this ecological response unit.

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had high-severity, stand-replacing fires where greater than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35-100+ years (fire regime IV). However some areas experienced high-severity, stand-replacing, fires where more than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0-35 years (fire regime II).

Fire current conditions: Fire return interval = 128 years

Fire severity: Non-lethal = 75 percent. Mixed-severity = 20 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 22 percent. Class II = 78 percent. Class III = 0 percent

Insects and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystem

- High: yellow starthistle (*Centaurea solstitialis*), fountain grass (*Pennisetum setaceum*), sweet resinbush (*Euryops subcarnosus*)
- Moderate: diffuse knapweed (*Centaurea diffusa*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Fifty-one acres of noxious weeds have been mapped in this ecological response unit.

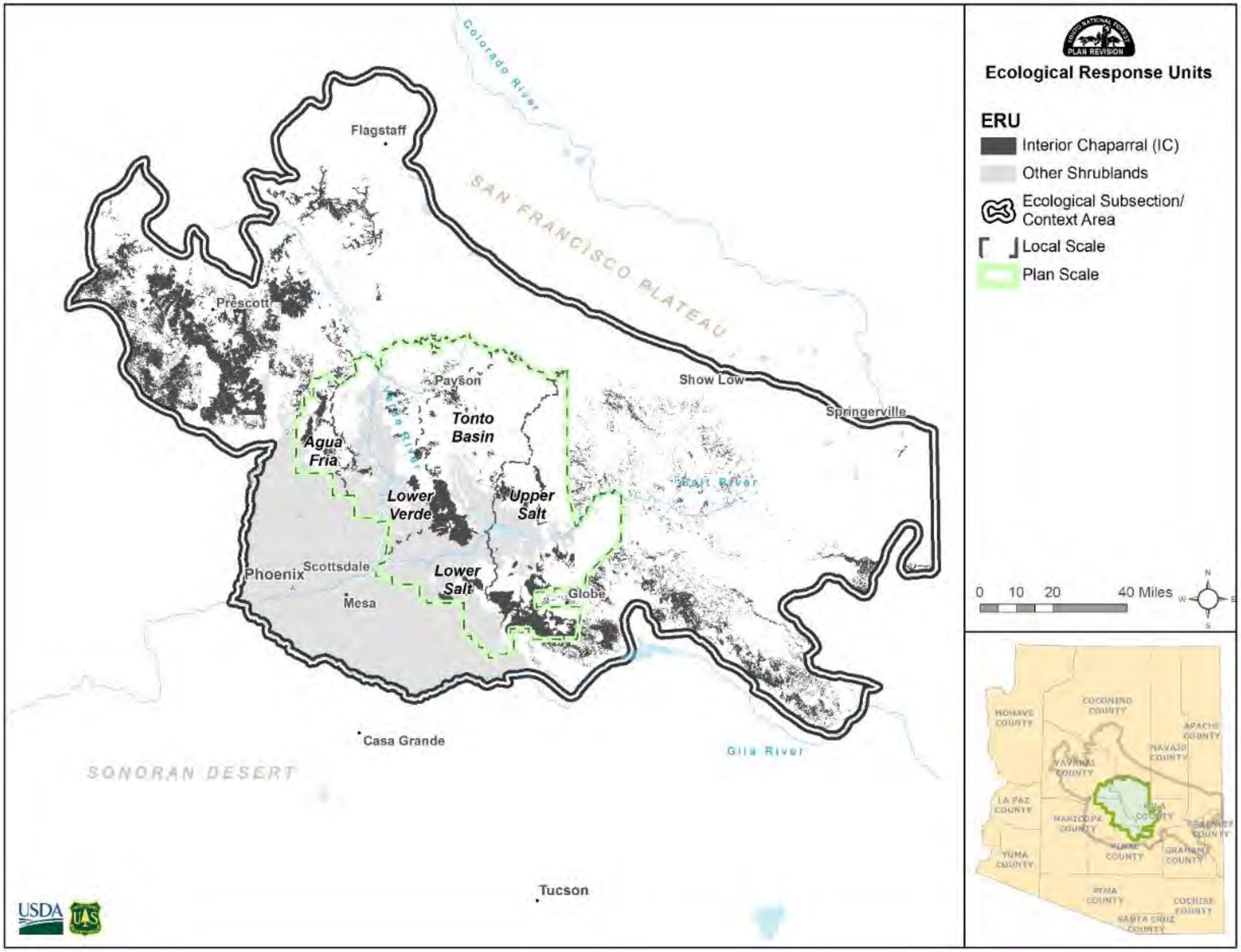


Figure 11. Interior Chaparral ecological response unit

Semi-Desert Grassland (SDG)

Elevation: 1,800 – 6,800 feet

Table 23. Distribution (acres and percent) at the context, plan, and local scales for Semi-Desert Grassland

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
1,718,290	340,983	42,283	56,117	42,337	148,129	52,118
14%	12%	24.9%	7.3%	6.8%	19.4%	12.0%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 24. Terrestrial ecosystem niche, Semi-Desert Grassland

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
19.8%	-0.07	Low

Photo 4. Semi-Desert Grassland

The Semi-Desert Grassland ecological response unit is found at elevations ranging from 3,000 to 4,500 feet bordering chaparral at high elevations and Chihuahuan desert at low elevations. Black grama (*Bouteloua eriopoda*) and tobosa grass (*Hilaria mutica*) are key diagnostic plants typically found at gravelly upland sites and in heavy soils at lowland sites, respectively (Brown and Makings 2014). Common grassland associations by dominant species include blue grama (*Bouteloua gracilis*) grassland, curly mesquite (*Hilaria belangeri*) grassland, and giant sacaton (*Sporobolus wrightii*) grassland (Wahlberg et al. 2013). Other grassland associations include mixed native perennial grassland and nonnative perennial grassland. Historically, tree abundance was less than 10 percent, while some areas may have had over 10 percent shrub cover. Soils and topography have strong influences on species composition and dominance in these systems. Desert scrub species can be common in this ecological response unit, making it difficult to distinguish desert communities from desert grasslands in some areas (Wahlberg et al. 2013). Short leguminous trees, such as mesquite and acacia, are commonly associated with desert grasslands. Many other locally important species contribute to the diverse assemblage of scrub and shrub components of semi-desert grasslands. Chollas and other cacti are also commonly associated with semi-desert grasslands. The Semi-Desert Grassland ecological response unit makes up 12 percent of the Tonto National Forest with more acres in the Upper Salt zone and the rest more or less equally distributed across the other local zones.

Reference Conditions

The Semi-Desert Grassland reached its greatest development among valleys, open hills, slopes, and ridges where winds carried lightning-caused fires (Brown and Makings 2014). The various unique grassland associations are the result of differences in climate, soil, topography, and parent materials across landscapes. Semi-desert grasslands are reliant on stand replacing fire return intervals of 0-35 years to maintain open productive grasslands. Historically, pre-monsoon lightning activity provided the ignition source that would burn vegetation until fuels were depleted or suppressed from rain (Wahlberg et al. 2013). Fire has been noted as one of the most important factors in maintaining open productive grasslands and limiting shrub encroachment. Many of the shrubs found in semi-desert grasslands are easily killed by fire and take up to 10 years to produce viable seeds, further supporting the important role of fire in these ecosystems. For example, young mesquite seedlings and saplings (less than 2 inches) have a higher mortality rate from fires than established individuals (Reynolds and Bohning 1956). Most perennial grasses can recover in as little as 1 to 2 growing seasons after a fire. The response of grasslands to fire are also tied to the amount of precipitation before and after fires (Finch 2004). The role of fire among black-grama-dominated grasslands is not well understood. In general, these grassland communities respond negatively to fire, and it is suggested they evolved with a much less frequent fire regime (Schussman and Smith 2006).

The highly productive nature of grasslands is largely attributed to the hydrological, biological, and geochemical cycling at sites (Finch 2004). Also, numerous mammals, birds, and reptiles contribute to the high biodiversity productivity of semi-desert grasslands. In particular, prairie dogs and their colonies have strong relationships with grassland communities; they affect soils, vegetation structure, species composition, biological diversity, and plant nutrient levels.

Current Conditions

The most pronounced changes to Semi-Desert Grasslands has been an overall shift from predominately open perennial grasslands to mixed grasslands (shrub, tree, and perennial grass) and converted shrublands at areas. Fire suppression (and exclusion), urban expansions, land development and historic grazing have contributed to shrub/tree encroachment, reduced productivity and lowered species diversity among Semi-Desert Grasslands.

Lower-elevation sites are generally more departed from reference conditions. However, some areas at valley bottoms with well-developed deep soils have not experienced shrub or tree encroachment from the absence of fire and or a history of livestock grazing (Schussman and Smith 2006). Historically, bunch grasses dominated many semi-desert grasslands forming clumps with bare ground interspaces. Today, some areas have experienced a shift from bunch grasses to sod grasses, such as curly mesquite, from a history of heavy livestock grazing. Where winter precipitation and disturbance is high, smaller native shrubs such as turpentine bush (*Ericameria laricifolia*) can invade and locally reach dominance. At disturbed sites with less summer rainfall, bunch grasses have been replaced by annual grasses and shrubs (Brown and Makings 2014). In west-central Arizona, perennial, warm-season grasses have been largely replaced by introduced annuals such as red brome.

Arroyo formation among valley bottoms during the late 19th and early 20th century have altered many semi-desert grasslands in the Southwest. This has resulted in a loss of fertile soils, increased sedimentation, altered hydrological function, and overall change from lush grasslands to xeric communities (Cooke and Reeves 1976). The exact causes of arroyo formation are difficult to assess but include factors such as climate change, land use, vegetation change, and livestock grazing (Schussman and Smith 2006). Roads, ditches, canals and the building of embankments were also factors that influenced arroyo formation.

Population expansion in central and southeastern Arizona has contributed to fragmentation among semi-desert grasslands. The elimination of large fires from suburban development that created artificial firebreaks from roads and development, resulted in the elimination of several open land-scape adapted species, such as pronghorn (*Antilocapra americana*), throughout their former range (Neff 1986; Ockenfels et al. 1996). The eradication of prairie dogs has had negative impacts on semi-desert grasslands including lowered nutrient cycling and lowered plant and animal diversity. Increased shrub/tree encroachment has also been influenced by the removal of prairie dogs as they reduce woody seedling establishment (mesquite) through herbivory (Reynolds and Bohning 1956).

When grass cover is reduced following disturbance, woody shrubs and other desert plants establish. Without frequent fires, changes in the surface soils over time will favor deep-rooted shrubs and trees over shallow-rooted grasses resulting in an almost irreversible cycle (McAullife 1997). Many sites today are in a disclimax state where soil-binding perennial grasses have been replaced by native and nonnative shallow rooted shrubs and annuals that compete with grasses. As a result, many of these sites now resemble an open “soft chaparral” type (Brown and Makings 2014). This change is highly variable and depends on local site conditions such as soil type, location, substrate characteristics, and level of disturbance.

Under reference conditions a majority of acres (70 percent) would be in the high seral state (B) where a majority of the vegetation is composed of perennial grasses and late successional herbaceous plants with shrub and tree cover collectively less than 10 percent. Twenty-five percent of the vegetation would have been perennial-mixed grasses with shrub and tree cover collectively less than 10 percent. Less common, representing 5 percent of vegetation, low-mid seral states consisted of perennial-mixed grasses and forbs with various shrub and tree cover. Contemporary states (E and F) are novel-low seral states with exotic grasses and various shrub and tree cover.

Current conditions show very high departure at the plan and context scales; however, departure is slightly lower at the context scale. Trends in seral state proportions are more or less the same across scales (local, plan, and context) with more acres in the low to mid seral states (C, D) and fewer acres in the high seral states (B). On the Tonto National Forest, a majority of the acres are nearly split between open and closed (C, D) and closed states (E). This is very different than the context scale where most of the acres are in open and closed (C, D) and only 4 percent are in closed states (E). The exotic low seral state (F) is more common at the context scale; however, the Agua Fria zone does have the highest proportion at 1.3 percent.

The higher proportion of closed states on the national forest suggests shrub/tree encroachment has occurred at many areas of the Tonto. This is also evident by the much smaller average patch size of 47 acres from reference conditions (1,015 – 1,343 acres). The fewer number of acres in closed states at the context scale may partially be explained by differences in grassland response at lower elevation sites. For example grasslands at valley bottoms with well-developed soils experienced less negative impacts despite fire suppression, drought, and livestock grazing (McAuliffe 1995). Reasons for the wide differences in resilience among semi-desert grasslands regionally are unclear, however higher precipitation at sites may be a factor as well (Schussman and Smith 2006).

Conversion from open to more closed conditions are evident by the very low similarity to site potential. Many shrubs and subshrubs are overrepresented on the national forest, such as broom snakeweed (*Gutierrezia sarothrae*), and buckwheat (*Eriogonum*). These shrubs commonly invade grasslands and can reach dominance at sites with a history of heavy grazing (Brown and Makings 2014). Many native bunch grasses are also poorly represented while sod-forming grasses have increased in abundance at areas. The shift from bunch forming grasses to sod-forming grasses are an indication of altered site conditions from disturbance. Velvet mesquite (*Prosopis velutina*) and catclaw acacia (*Acacia greggii*) are also well above the similarity to site potential at many areas further confirming the occurrence of shrub encroachment at sites. The effects are most pronounced at the Upper Salt zone with 48 percent of the acers in closed grass, shrub/tree conditions (E). Fungi and soil crusts play key roles in ecological functioning and significantly reduce erosion potential from wind and water. Repeated disturbance can significantly reduce or eliminate biological crusts that can negatively affect seedling germination, plant growth, and nutrient levels (Belnap et al. 2001). The loss of biological crusts have likely contributed to the lowered site productivity Semi-Desert Grassland.

The loss of frequent high severity fires has also strongly influenced grassland conversion to shrubland. Fire return intervals in semi-desert grasslands on the Tonto National Forest currently average 210 years. Most fires have been non-lethal to mixed-severity fires, while only 6 percent have been stand-replacing. This change in fire has favored the continued establishment of woody species and elimination of grasses and herbs. The lack fine fuels to carry fires are also evident by the low vegetative ground cover at many areas.

Future Trend

Departure is projected to be the same (high departure); however, with some notable differences in vegetation structure. Projections (Vegetation Dynamics Development Tool modeling) show most acres moving out of the low-mid seral open and closed state (C, D) to the low seral exotic state where the herbaceous layer is dominated by exotics (F). The altered fire regime along with exotic grasses are strongly influencing projections of decreased open conditions. The increase in some exotics, such as Lehmann lovegrass, have been described as having a positive feedback loop where initial benefits (such as providing fine fuels and increasing fire frequency) eventually result in negative impacts such as increasing the extent of less-desirable exotic grasses, lowering biodiversity and increasing fire intensity.

While the opportunity for the Tonto National Forest to contribute to the sustainability of this ecological response unit at the context is low, these community types are at high risk on the Tonto National Forest, outside the Tonto National Forest (context), and regionally (Arizona and New Mexico). According to the Arizona Grasslands Assessment (Schussman and Gori 2004), The Tonto National Forest was identified as having more restorable acres of semi-desert grasslands compared to other landowners (private, state, and federal) and national forests regionally. Also, while very few acres are in open perennial grass states, nearly half Semi-Desert Grassland acres are in fire regime condition class II (52 percent). The ability to restore ecosystem components for these acres are much higher than the 48 percent that are in fire regime condition class III. For these reasons, the Tonto National Forest has a high potential to contribute to ecosystem maintenance for semi-desert grasslands regionally. While Semi-Desert Grassland on the Tonto is the least common at the Agua Fria zone, it makes up the second most abundant community type (Juniper Grass being the most abundant) at the Agua Fria zone and has the highest proportion of exotics compared to all other zones and the context scale.

Numerous attempts to restore Semi-Desert Grassland regionally consist of controlled burns, reduced grazing, and reseeding; however, it’s unclear whether or not these areas will return to their historic state (Brown and Makings 2014). Degraded site conditions allow the establishment and spread of exotic forb and grass species that can displace native species and increase fire frequency. For example, shrub encroachment may increase wildlife habitat for generalist but reduce habitat for grassland specialists (Knopf 1992).

Restoration efforts should be directed towards maintaining soil health and productivity, key ecosystem processes (for example, fire), and community structure (for example, representation of soil-binding species such as bunch-forming grasses) to improve overall ecological integrity. Some grasslands need 1 to 3 seasons of rest between burns, whereas others may require longer periods to obtain sufficient fuel loads (Schussman and Gori 2004). Caution should be taken when burning areas dominated by nonnative grasses as information on post-fire regeneration for many is lacking and fires can increase establishment of nonnatives (Schussman and Gori 2004).

Semi-Desert Grassland (SDG)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[1] (100 years)**
A	Post Disturbance (open)	25	2.8	3.6	1.5	0.6	0.1	0.2	0.8	0.0
B	High Seral	70	14.5	0.6	0.1	0.3	0.2	0.1	0.2	0.1
C, D	Low-mid Seral, Ruderal Grass, Shrub (open and closed)	5	77.5	57.5	51.0	67.1	51.4	57.7	55.0	9.1
E	Low Seral, Ruderal Grass, Shrub (closed)	0	4.3	37.1	47.0	31.4	48.1	41.9	43.5	39.1
F	Low Seral Exotics	0	0.8	1.3	0.3	0.6	0.3	0.2	0.4	51.8
		Departure[2]:								

1. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale), see “Seral State Proportion” section for more information.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 1,015 to 1,343 acres. Current patch size = 47 acres. Departure = high, much smaller

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Overall, native buckwheat (*Eriogonum spp.*) and broom snakeweed (*Gutierrezia sarothrae*) have increased in abundance.

Graminoids: Many of the potential grasses present have low abundance, such as sideoats and hairy grama (*Bouteloua curtipendula* and *Bouteloua hirsuta*). Curlymesquite grass (*Hilaria belangeri*) has significantly increased in abundance in some areas.

Shrubs and trees: Many shrubs and trees, such as velvet mesquite (*Prosopis velutina*), catclaw acacia (*Acacia greggii*), catclaw mimosa (*Mimosa aculeaticarpa*), desert ceanothis (*Ceanothis greggii*), red barberry (*Mahonia haematocarpa*), Sonoran scrub oak (*Quercus turbinella*) and others, have significantly increased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (12%)	Low (24%)	Moderate (34%)	Low (13%)	**Low (15)**
Species present/potential Species	40/89	33/66	62/95	10/11	

1 Forbs include all herbaceous flowering plants.

2 Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 28 percent

Current = 14 percent

Departure = Moderate (46)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See "Vegetative Groundcover" section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags analysis does not apply to this ecological response unit.

Ecosystem Drivers and Stressors

Fire reference conditions: The fire regime for this ecological response unit is defined as having high-severity, stand-replacing, fires where more than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime II).

Fire current conditions: Fire return interval = 210 years
Fire severity: Non-lethal = 72 percent. Mixed = 22 percent. Stand-replacing = 6 percent
Fire regime condition class: Class I = 0 percent. Class II = 52 percent. Class III = 48 percent

Insect and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: yellow starthistle (*Centaurea solstitialis*)
- Moderate: Canada thistle (*Cirsium arvense*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

No acres of noxious weeds have been mapped in this ecological response unit.

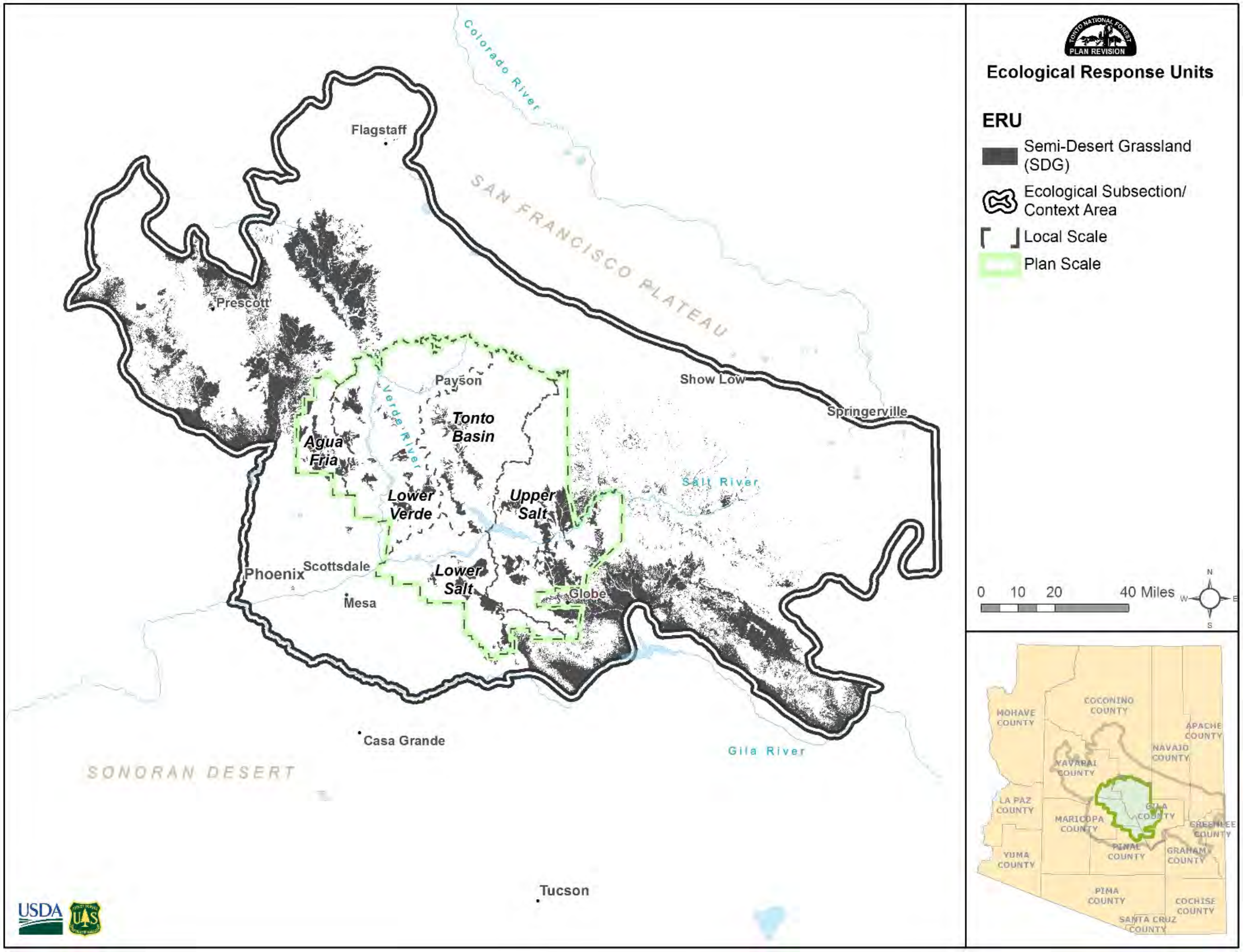


Figure 12. Semi-Desert Grassland ecological response unit

Pinyon-Juniper Woodland (PJO)

Elevation: 2,300 – 7,300 feet

Table 25. Distribution (acres and percent) at the context, plan, and local scales for Pinyon-Juniper Woodland

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
276,149	54,352	289	32,503	13,582	7,978	
2%	2%	0.2%	4.2%	2.2%	1.0%	

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 26. Terrestrial ecosystem niche, Pinyon-Juniper Woodland

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
19.7%	-0.07	Low

Photo 5. Pinyon-Juniper Woodland

Typical species for Pinyon-Juniper Woodland include twoneedle pinyon (*Pinus edulis*), single leaf pinyon (*Pinus monophylla* var. *fallax*), Utah juniper (*Juniperus osteosperma*), oneseed juniper (*J.* monosperma), and alligator juniper (*J. deppeana*). Pinyon-Juniper Woodland is a broad grouping of different plant associations with trees occurring as individuals or in smaller groups and range from young to old, but more typically as large, even-aged structured patches. Pinyon-Juniper Woodland characteristically has a moderate to dense tree canopy and a sparse understory of perennial grasses, annual and perennial forbs, and shrubs. Woodland development occurs in distinctive phases, ranging from open grass-forb, to mid-aged open canopy, to mature closed canopy. Some types on broken or rocky terrain exhibit little to no natural fire, and insects and disease may be the only disturbance agents. Mostly found on lower slopes of mountains and in upland rolling hills at approximately 4,500 to 7,500 feet in elevation. Most common pinon pine is the two-needle pinon occurring in limited areas. One-seed juniper is most common; however, there are areas with Utah juniper and Rocky Mountain juniper. In addition, annual and perennial grasses and graminoids, forbs, half-shrubs and shrubs can be found beneath the woodland overstory.

The Pinyon-Juniper Woodland ecological response unit covers 54,352 acres on the Tonto National Forest and 276,149 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto (2 percent) is similar to the context area (2 percent). With a very low proportional representation on the Tonto (-0.07), the opportunity for the Tonto National Forest to influence context scale conditions for this ecological response unit is low. The Pinyon-Juniper Woodland ecological response unit is present in four of the five local zones. Most acres are located in the Lower Verde zone (32,503 acres), and Tonto Basin zone (13,582 acres) with a lesser amounts in the Upper Salt zone (7,978 acres) and the Agua Fria zone (289 acres).

Reference Conditions

Historically, the Pinyon-Juniper Woodland was characterized by even-aged patches up to hundreds of acres. Old growth was concentrated in stands or larger areas, and very old trees (over 300 years) were present. Overall, 60 percent of trees were medium to large (greater then10 inches diameter at breast height). At the landscape scale, the mosaic of disturbance history and physical site potential resulted in a variety of ages and stand structures (Huffman et al. 2008). Over 75 percent of stands were dense, with closely spaced trees and a closed canopy (Dick-Peddie 1993; LANDFIRE 2010). Huffman and others (2008) reconstructed 1890 tree density and found an average of 177 trees per acre.

Even though the Pinyon-Juniper Woodlands ecological response unit supports reasonable fuel loads of both dead and live material, the fuels are very patchily distributed. Patches of heavy fuels are typically separated by comparably sized patches of rock, bare ground, or sparse cover of herbs that do not carry fire readily. Because of the lack of horizontal fuel continuity, fire spread was typically under conditions of strong winds and extremely low fuel moisture (Romme et al. 2003). Typical disturbances (fire, insects, and disease) were of high severity and occurred infrequently with a historic fire return interval of 30 to 200 years from stand-replacing fire. These disturbance patterns create and maintain the even-aged nature of this type. Widespread fire was rare, in most cases fire return intervals were on the order of centuries, up to 400 years or more (Huffman et al. 2008). The historic extent and pattern of stand replacing fires have not been well quantified since Pinyon-Juniper Woodlands would burn completely or not at all, making crossdating of fire-scarred trees difficult (Huffman et al. 2008). Most fires likely burned single trees or small patches but had little effect on woodland structure overall (Romme et al. 2009).

Stand structure and extent of Pinyon-Juniper Woodlands were more likely driven by climate fluctuation and insect and disease outbreaks than by fire. The resultant tree expansion and contraction along grassland and shrubland borders has likely occurred cyclically for thousands of years (Romme et al. 2009). Drought and pinyon pine *Ips* beetle outbreaks occurred in 2002 to 2004 and in the 1950s but have also been well documented during a severe drought in the 1500s (USDA Forest Service 2014b). There is a high probability that individual pinyon pine trees will experience killing drought during their lifespan (Romme et al. 2009). Altogether, pinyon pine populations are often affected by disturbance and rarely reach equilibrium (USDA Forest Service 2014b).

Current Conditions

Current conditions on the Tonto show a shift toward the more open states in both the medium/large and small tree states. The early development, post disturbance grass/forb/shrub state is slightly above reference condition levels at 16 percent. Current conditions at the context scale are similar to the planning scale with a similar shift toward the more open states, but to a slightly lesser degree, and the early development, post disturbance grass/forb/shrub state at the context scale is slightly below the reference condition levels at 8 percent. The departure rating at both scales is low. The departure rating for each of the four local zones is slightly different from each other. The Tonto Basin and Upper Salt zones are showing departure ratings of low, while the Lower Verde and Agua Fria zones are showing departure ratings of moderate.

The Upper Salt zone is the least departed of all the zones with a very low departure rating of 14 percent. With 64 percent in the combined medium/large states and just a little excess in the small closed state (23 percent), this zone is very close to reference conditions. The Tonto Basin zone is slightly more departed with a departure rating of 29 percent. This departure is similar to the departure found at the planning scale in both the types of departure and the amounts of departure. Together these two zones comprise 85 percent of the Pinyon-Juniper Woodland on the Tonto National Forest and are responsible for the low plan scale departure.

The Lower Verde zone is very similar to the planning scale departure but has a departure rating of moderate (36 percent) due to slightly less area in the medium/large states. The Agua Fria zone is showing the highest level of departure with a departure rating of moderate (59 percent). The departure in the Agua Fria zone is different from the other zones in that it has much less of the medium/large tree states (20 percent) and an unusually high percentage of the seedlings and saplings and small tree open state (49 percent). The higher departures seen in the Tonto Basin and Lower Verde zones are likely the result of the 2004 Willow Fire which burned through a portion of the Pinyon-Juniper Woodland in these zones. In the Agua Fria zone, the 2005 Cave Creek Complex burned through all the Pinyon-Juniper Woodland contained in the zone. This ecological response unit is also highly susceptible to the effects of insects and pathogens when stressed. Dry conditions and the severe outbreak of pinyon bark beetles that occurred in 2003 contributed increased coarse woody debris and fuel just prior to the fire events.

Fire exclusion probably has had little effect on Pinyon-Juniper Woodlands, since fire return intervals are naturally very long in this ecological response unit (Romme et al 2003). The current fire return interval of 201 years is well within the historic range. Drought conditions beginning in the late 1990s initiated a bark beetle outbreak in 2003. This has resulted in an increased number of snags and the accumulation of coarse woody debris. Coarse woody debris has increased to 17.3 tons per acre and the number of snags is now just over 10 per acre. This large loading in coarse woody debris is expected in vegetation types with long fire intervals but not in this ecological type, as it is site limited by nutrient and water availability. Patch size has also decreased, along with a decrease in the diversity of grasses and forbs and a reduction in vegetative ground cover.

Future Trend

Modeling predicts continued growth into the medium/large state class with the majority moving into the medium/large open state class. The proportions of medium/large open and medium/large closed state are predicted to be nearly equal by year 100. Grass/forb/shrub, small closed, and seedling/saplings are predicted to decrease to levels near or slightly lower then reference conditions in the next 100 years under current management.

Predictions indicate the medium/large closed state will remain well below reference conditions of 60 percent. This can be attributed to this systems susceptibility to the effects of insects, pathogens, and climate change. Once the system is opened, as it has been by the insect outbreak in 2003, the closing of canopies can require extended periods of time. Open canopies and smaller patch sizes with large gaps can allow for the expansion of brush species into the openings. As bush species expand, grass and forb production is reduced and less space is available for tree seedling establishment. Insect outbreaks also result in an increase in the number of smaller snags per acre less than 8 inches in diameter which will eventually lead to the further accumulation of coarse woody debris as these snags fall.

Pinyon-Juniper Woodland (PJO)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A	Grass/Forb/Shrub	10	8	22	16	21	7	----	16	9
F	Small (closed)	15	14	8	18	13	23	----	17	8
B, E, C	Seedlings/Saplings and Small Trees (open)	5	15	49	24	17	6	----	20	7
D	Medium/Large (open)	10	23	12	18	16	16	----	17	39
G	Medium/Large (closed)	60	40	8	24	33	49	----	30	38
		Departure[3]:	23 (L)	59 (M)	36 (M)	29 (L)	14 (L)	----	30 (L)	31 (L)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale), see “Seral State Proportion” section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 50 to 400 acres. Current patch size = 24 acres. Departure = moderate, smaller

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Overall forb abundance is low, with the exception of increases in herbaceous burclover (*Medicago spp.*) at some locations.

Shrubs and trees: Wright’s silktassel and Sonoran scrub oak (*Garry spp.*, and *Quercus turbinella*) have increased in abundance, while pointleaf manzanita and single-leaf pinyon (*Arcostaphylos pungens* and *Pinus monophylla*) have decreased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (22%)	Moderate (50%)	Moderate (57%)	Moderate (65%)	**Low (30)**
Species present/potential Species	2/6	9/15	18/20	6/6	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 71 percent

Current = 29 percent

Departure = Moderate (39)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse woody debris and snags

Reference: Coarse woody debris = 4.0 tons per acre. Snags greater than 8 inches = 2.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 17.3 tons per acre. Snags greater than 8 inches = 8.4. Snags greater than 18 inches = 1.8

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had high-severity, stand-replacing, fires where greater than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 200+ years (fire regime V). However some areas did experience mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III).

Fire current conditions: Fire return interval = 201 years

Fire severity: Non-lethal = 68 percent. Mixed = 27 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 20 percent. Class II = 80 percent. Class III = 0 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed. A survey in 2003 showed an unprecedented, severe outbreak of pinyon bark beetles.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: Russian knapweed (*Acroptilon repens*), sweet resinbush (*Euryops subcarnosus*)
- Moderate: Malta starthistle (*Centaurea melitensis*), Dalmatian toadflax (*Linaria dalmatica*), diffuse knapweed (*Centaurea diffusa*), yellow starthistle (*Centaurea solstitialis*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

No acres of noxious weeds have been mapped in this ecological response unit.

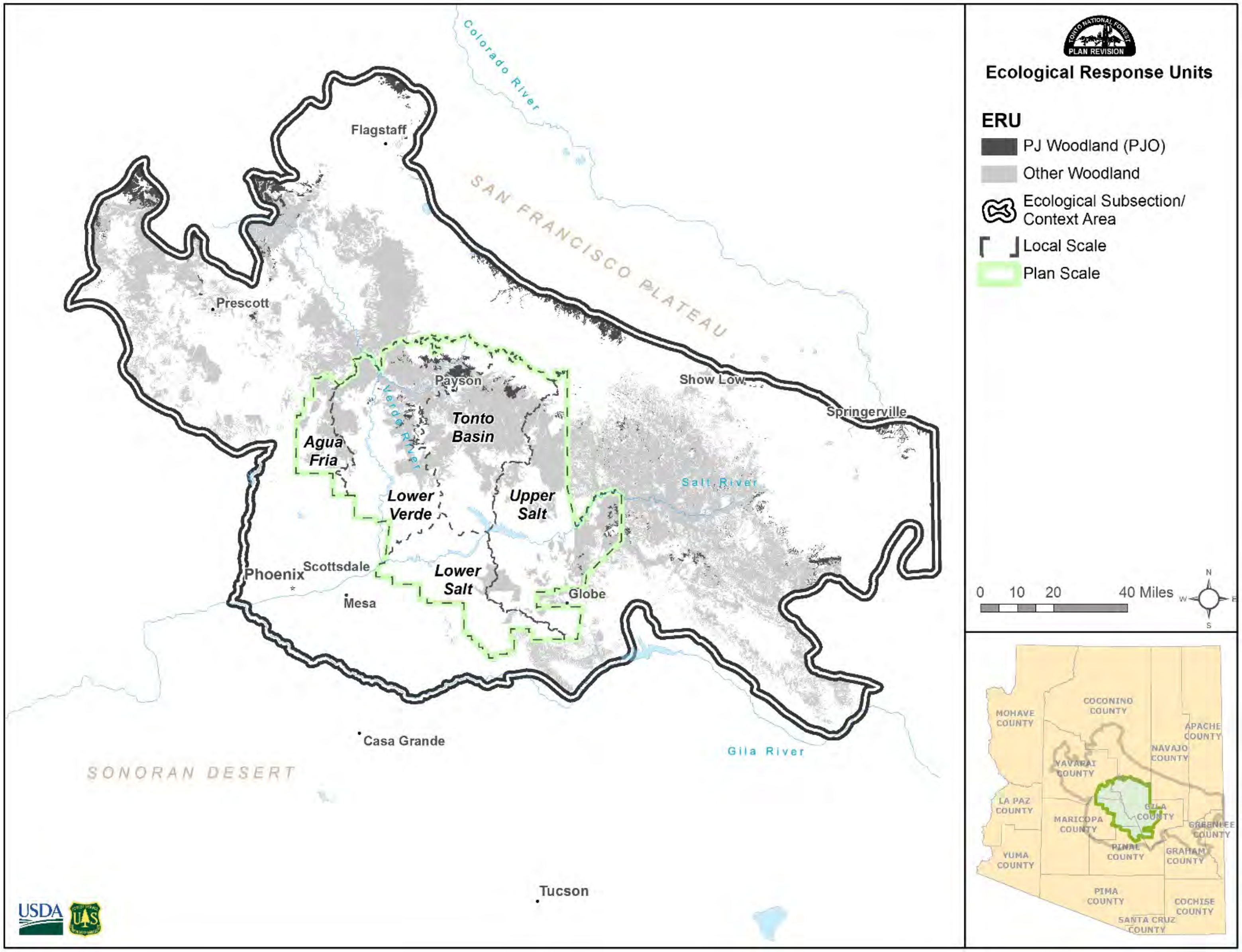


Figure 13. Pinyon-Juniper Woodland ecological response unit

Juniper Grass (JUG)

Elevation: 2,200 – 7,600 feet

Table 27. Distribution (acres and percent) at the context, plan, and local scales for Juniper Grass

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
647,511	415,546	62,022	158,517	91,348	99,753	3,906
5%	15%	36.5%	20.5%	14.7%	13.1%	0.9%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 28. Terrestrial ecosystem niche, Juniper Grass

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
64.2%	0.47	High

Photo 6. Juniper Grass

Juniper Grass is typically on warmer and drier settings beyond the environmental limits of pinyon pine, and just below, and often intergrading with, the pinyon-juniper zone. However Juniper Grass tends to be restricted to warmer and drier settings that limit pinyon (Wahlberg et al. 2013). Mollisol soils are common for this ecological response unit and support a dense herbaceous matrix of native grasses (mostly perennials) and forbs. Typical disturbances (fire, insects, and disease) are of low severity and high frequency with a historic average fire return interval of 0 to 35 years from low to moderate severity fires. These disturbance patterns create and maintain the uneven- aged, open-canopy nature of this type. Typically, native understory grasses are perennial species, while forbs consist of both annuals and perennials. Shrubs are characteristically absent or scattered. This type is typically found on sites with well-developed, loamy soil characteristics, generally at the drier edge of the woodland climatic zone. Generally these types are most extensive in geographic areas dominated by warm (summer) season or bi-modal precipitation regimes. Overall, these sites are less productive for tree growth than the Pinyon-Juniper Woodland type.

The Juniper Grass ecological response unit covers 415,546 acres on the Tonto National Forest and 647,511 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto National Forest is 15 percent of the land area, substantially more the context area representation of 5 percent. This high proportional representation on the Tonto means the sustainability of this system at the context scale is highly sensitive to conditions on the planning scale. The juniper grass ecological response unit occurs in in all five local zones. The majority is in the Lower Verde (158,517 acres), Upper Salt (99,753 acres), and Tonto Basin zones (91,348 acres). A little lesser amount (62,022 acres) occurs in the Agua Fria zone and minimal amount (3,906 acres) can be found in the Lower Salt zone.

Reference Conditions

The Juniper Grass ecosystem is generally uneven-aged and very open in appearance. Trees occur as individuals or in smaller groups with the majority (60 percent) of medium to large in size. Like many of the other woodland types, a fair proportion (35 percent) of small trees is also represented on Juniper Grass landscapes. Snags are not prevalent but exist, roughly four per acre with the majority being smaller in diameter. The dense herbaceous matrix of native grasses and forbs along with the frequent disturbance limit the average patch size from 0.07 to 0.5 acres. The herbaceous understory encourages frequent low-severity wildfire to occur every 8 to 30 years depending on site conditions. Limited overstory tree cover and woody plants limit the amount of coarse woody debris to 3.0 tons per acre. Despite the presence of a well-developed herbaceous layer, over a quarter of the soil surface is exposed and the amount of ground litter is significantly less relative to all other ecological response units.

Current Conditions

The Juniper Grass ecological response unit is moderately departed at both the planning scale and the context scale. Multiple wildfires and management are largely responsible for the current conditions found on the planning scale. The planning scale show a significant shift toward the early development states with 67 percent of this ecological response unit in the grass and forb state, and just under 20 percent in the late development, medium to large tree states. The majority of the medium/large tree state on the plan scale is in a closed canopy condition (13 percent) with only 6 percent in the open canopy condition. With conditions on the Tonto National Forest closely correlated to the conditions at the context scale, it is no surprise that the context scale shows a similar shift. The context scale departure is slightly lower than the planning scale, with 56 percent in the grass and forb state and 30 percent in late development medium to large tree states evenly split between the open and closed states. At the local zones, the Lower Verde, Upper Salt, and Agua Fria zones are similar to the planning scale in both the level and type of departure, with moderate departures of 65 percent in the Lower Verde and Upper Salt zones and 64 percent in the Agua Fria zone. The Tonto Basin and Lower Salt zones are showing high departure ratings. This increase in departure rating is the result of even higher percentages in the grass/forb/shrub state. In the Tonto Basin zone, 72 percent of the area is in the grass/forb/shrub state and in the Lower Salt zone 93 percent of the area is in the grass/forb/shrub state. A great deal of this shift to the grass/forb/shrub state can be attributed to six wildfires that burned through this ecological response unit within the last twelve years. The 2004 Willow Fire in the Lower Verde and Tonto Basin zones, the 2005 Cave Creek Complex in the Agua Fria zone, the 2005 Peachville fire in the Lower Salt zone and in 2012 the Sunflower Fire in the Agua Fria zone, the Mistake Peak Fire in the Tonto Basin zone and the Queen Fire in the Lower Salt zone.

Repeated wildfires, range management activities and grazing have all contributed to an increases in patch size. Patches now average 30 acres at the plan scale, which is highly departed from the small patch sizes of one half acre or less found in the reference condition. An increase in coarse woody debris, a decrease in ground cover, and a reduction in the diversity of grass, forbs, and shrubs are also likely result of repeated wildfires and grazing. Historically, these system burned under a frequent, non-lethal fire regime with a fire return interval of 0-35 years. Now they are experiencing fire return intervals of up to 96 years with 21 percent of these fires burning with mixed-severity and 5 percent burning with stand-replacing intensity. Many of these sites now have insufficient ground vegetation to carry non-lethal surface fire.

Future Trend

Vegetation Dynamics Development Tool models predict the amount of grass/forb/shrub state on the plan scale to decrease to 13 percent by year 100. This is still above the reference condition of 5 percent. The small closed state and the seedling and sapling small tree open state will remain relatively constant with a slight decrease in both states. The medium/large open state and the medium/large closed state are predicted to increase, as tree diameter increase, with the majority of the increase occurring in the medium/large open state. The medium/large open state is predicted to be near the reference condition at 46 percent by year 100, just slightly below the 50 percent found in the reference condition. The medium/large closed state is expected to reach 34 percent a condition that accounted for only 10 percent in the reference condition. The trend toward the closed state is predicted to continue well into the future, well beyond 100 years.

Past wildfires and current management has created and maintained a higher proportions of the juniper grass ecological response unit in the grass/forb/shrub state. This has put this ecological response unit on a trajectory that, in the future, will bring it closer to reference conditions with a predicted departure at 100 years of 32 percent (low). With continued fire suppression, livestock grazing and an absence of disturbance the small closed state and some of the medium/large open state will continue to move into the medium/large closed state as the in-filling of the canopy gaps continues. With 34 percent of this ecological response unit remaining in a denser state in the future, it will continue to be susceptible to outbreaks of insects, pathogens and stand replacing wildfire.

Juniper Grass (JUG)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[1] (100 years)**
A	Grass/Forb/Shrub	5	56	65	65	72	66	93	67	13
F	Seedlings/Saplings and Small Trees (open)	25	8	11	11	5	9	0	5	3
B, E, C	Small (closed)	10	6	5	5	6	6	2	9	4
D	Medium/Large (open)	50	15	5	5	8	6	4	6	46
G	Medium/Large (closed)	10	15	14	15	9	13	1	13	34
		Departure[2]:	56 (M)	64 (M)	65 (M)	67 (H)	65 (M)	88 (H)	65 (M)	32 (L)

1. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale), see "Seral State Proportion" section for more information.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See "Seral State Proportion" section for explanation on departure calculation.

Average Patch Size (acres at plan scale). Reference patch size = 0.07 to 0.5 acres. Current patch size = 30 acres. Departure = high, much larger

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Almost all forbs, such as native buckwheat (*Eriogonum*) and broom snakeweed (*Gutierrezia sarothrae*), have increased in abundance.

Graminoids: Cane bluestem (*Bortriochloa barbinodis*), and sideoats grass (*Bouteloua curtipendula*) have increased in abundance, while curlymesquite grass (*Hilaria belangeri*) and muly grass (*Hilaria belangeri*) have decreased in abundance.

Shrubs and trees: Many shrubs, such as alder-leaf mountain-mahogany (*Cercocarpus montanus*) and Sonoran scrub oak (*Quercus turbinella*), have increased in abundance, while a few, such as crucifixion thorn (*Canotia holacantha*), have decreased in abundance. Utah and one-seed juniper (*Juniperus monosperma* and *Juniperus osteosperma*) are more abundant than redberry juniper (*Juniperus coahuilensis*) in some locations.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (14%)	Moderate (45%)	Moderate (54%)	Moderate (51%)	**Low (26)**
Species present/potential Species	26/69	25/49	30/44	9/9	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 49 percent

Current = 21 percent

Departure = Moderate (44)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 3.0 tons per acre. Snags greater than 8 inches = 3.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 8.8 tons per acre. Snags greater than 8 inches = 2.7. Snags greater than 18 inches = 0.7

Ecosystem Drivers and Stressors

Fire reference conditions: The fire regime for this ecological response unit is defined as having non-lethal (mostly surface fires) to mixed-severity fires, where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I).

Fire current conditions: Fire return interval = 96 years

Fire severity: Non-lethal = 74 percent. Mixed = 21 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 0 percent. Class II = 100 percent. Class III = 0 percent.

Insect and disease: Analysis does not apply to this ecological response unit.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: yellow starthistle (*Centaurea solstitialis*)
- Moderate: Canada thistle (*Cirsium arvense*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Seventy-six acres of noxious weeds have been mapped in this ecological response unit.

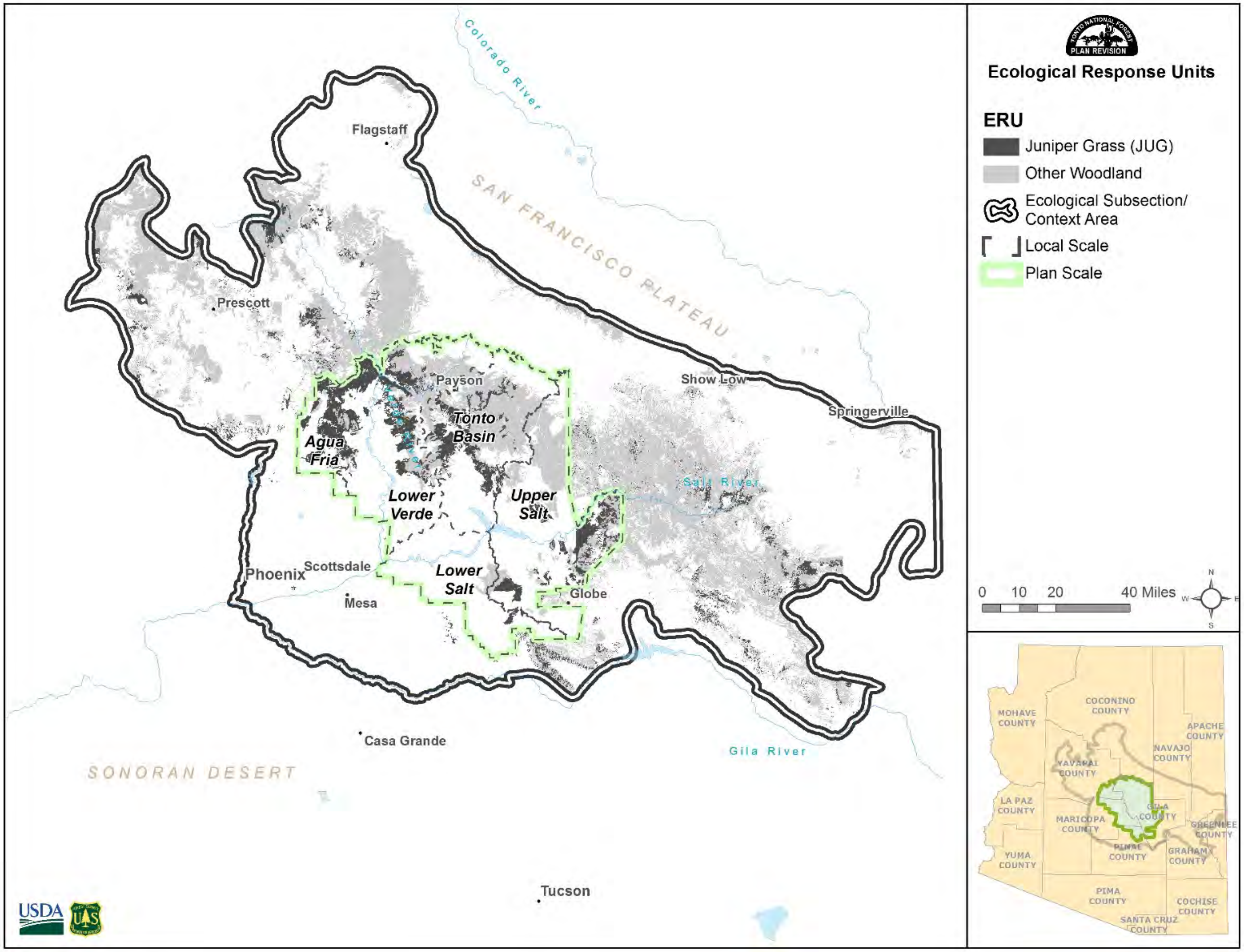


Figure 14. Juniper Grass ecological response unit at plan scale

Madrean Encinal Woodland (MEW)

Elevation: 3,400 – 6,700 feet

Table 29. Distribution (acres and percent) at the context, plan, and local scales for Madrean Encinal Woodland

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
154,815	93,157		10,938	67,375	14,823	21
1%	3%		1.4%	10.9%	1.9%	< 0.1%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 30. Terrestrial ecosystem niche, Madrean Encinal Woodland

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
60.2%	0.45	High

Photo 7. Madrean Encinal Woodland

The Madrean Encinal Woodland 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*) are the dominant species for this ecological response unit which historically had greater than 10% canopy cover (Wahlberg et al. 2013). Occasionally, madrean pine, Arizona cypress, pinyon, juniper, and interior chaparral species may be present. The groundcover is dominated by warm-season grasses. Grass species include threeawns (*Aristidateripes and A. schiedeana* var. *orcuttiana*), 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 emerslyi, M. pauciflora,* and *M. setifolia*), and Texas bluestem (*Schizachyrium cirratum*) (Wahlberg et al. 2013).

The Madrean Encinal Woodland ecological response unit covers 93,157 acres on the Tonto National Forest and 154,815 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto is 3.4 percent of the land area, more than twice the context area representation of 1.3 percent. This high proportional representation on the national forest means the sustainability of this system at the context scale is highly sensitive to conditions on the planning scale. The Madrean Encinal Woodland occurs in four of the five local zones. The majority (72 percent) is in the Tonto Basin zone (67,375 acres), the Lower Verde zone with 10,938 acres and Upper Salt zone with 14,823 acres account for most of the rest. A minor amount (21 acres) can be found in the Lower Salt zone.

Reference Conditions

Madrean encinal woodlands were historically dominated by an open stand of oaks with denser stands of oaks on north facing slopes and in drainages. Perennial grasses composed the understory and provided fuel for surface fires. Over the last 150 years, the Madrean Encinal Woodland has trended away from these open woodlands and towards woodlands with higher canopy cover and higher abundances of mesquite and juniper trees (Turner and others 2003). Regeneration of the dominant oak species is primarily due to re-sprouting following a disturbance with little regeneration from acorns due to dry conditions (Germaine and McPherson 1998). Additionally, drought has been suggested to cause mortality in oaks at the lower elevational boundary of this ecological response unit (Turner and others 2003).

Frequent fires, occurring primarily between April and June, have been well documented for the semi-desert grasslands and Madrean pine-oak woodlands that border the Madrean Encinal Woodland; however, little is known about the frequency of fire in southwestern oak woodlands (Bahre 1985; Fulé and others 2005; Humphrey 1952, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996; Swetnam and others 1992; Wright 1980). Given that fires in semi-desert grasslands occurred on average every 2.5 to 10 years, covered hundreds of square miles, and often spread to upper elevation Madrean pine-oak systems, which experienced fires on average every 3 to 7 years, it seems likely that the Madrean Encinal Woodland also experience frequent fires (Bahre 1985; Fulé and Covington 1998b; Fulé and others 2005; Kaib et al. 1996; McPherson 1995; Swetnam and Baisan 1996; Swetnam and others 1992). The ability of the dominant vegetation, evergreen oaks and perennial bunch grass, to recover quickly after fire also supports the idea of frequent fire in oak woodlands (Bock and Bock 1992; Cable 1972; Caprio and Zwolinski 1992; Martin 1983). Frequent fires kept fuel loads relatively constant spatially and temporally and encouraging understory herb cover. The frequent return of fire in these systems would limit the accumulation of coarse woody debris to levels around 2.2 tons per acre.

Current Conditions

Due to the effects of long-term fire exclusion and grazing in this type, the Madrean Encinal Woodland ecological response unit is moderately departed at both the national forest level and the context scale. The Tonto is showing a departure of 43 percent, while the context scale is slightly lower at 40 percent. The majority of this departure is due to a shift from small closed to the medium/large closed state which was not present under reference conditions. This is the result of the small closed state (40 percent of the ecological response unit under reference conditions) developing uninterrupted without the disturbance required to open canopies. The small closed state has decreased to 12 percent on the Tonto and 11 percent at the context scale, while the medium/large closed state has increased to 33 percent on the national forest national forest and 27 percent at the context scale. Without the level of disturbance required to regulate early successional development, the proportions in the seedling/sapling and small tree classes have also been reduced to 10 percent on the Tonto and 14 percent at the context scale, while grass/forb/shrub state has remained relatively constant at both scales showing a slight increase. This ecological response unit occurs in four of the five local zones, all of which are showing a departure rating of moderate. The majority of the Madrean Encinal Woodland ecological response unit occurs on the Lower Verde (10,938 acres), Tonto Basin (67,375 acres), and Upper Salt zones (14,823 acres), with a minor amount occurring on the Lower Salt zone (21 acres). The departure on the Tonto Basin (34 percent) and Lower Salt (43 percent) is similar to the departure found at the planning scale and the context scales in both the types of departure and the amounts of departure. The Upper Salt zone is showing a slightly higher level of departure (48 percent) due to a slightly larger percentage of the medium/large closed state and less of the seedling and sapling and small tree state. The departure on the Lower Verde is similar in scale (44 percent) but differs in the type of departure. The Lower Verde has less area in the medium/large closed state (15 percent) and a large increase in the amount of the grass/forb/shrub state (48 percent). The high percentage of the grass/forb/shrub state can be attributed to the 1995 Basin, 2004 Willow, and 2012 Sunflower fires in the Lower Verde zone.

Fire suppression and grazing have both contributed to a lengthening of the fire return interval to 170 years instead of the 0-35 years found under reference conditions. This has allowed the coarse woody debris to build up to 22.3 tons per acre and the number of snags greater than 8 inches to reach 5.6 per acre. This is good for providing wildlife habitat, but the large amounts of coarse woody debris are likely to increase fire behavior to the point where wildfires are more resistant to control. The in-filling of the canopy gaps and increased density of brush species in the medium/large closed state has led to a reduction in the abundance and diversity of grass and forb species and a reduction in vegetative groundcover. However, patch size has remained within the natural range of variation at 30 acres. The combination closed canopies, increased coarse woody debris, and reduced vegetative ground cover makes it difficult to reintroduce non-lethal fire into this system as a management tool without first modifying the distribution, spatial arrangement, and concentration of the current fuel loads.

Future Trend

Modeling of future conditions predicts the trend toward the medium/large closed state to continue in the absence of reoccurring disturbances and the Madrean Encinal Woodlands to remain moderately departed into the foreseeable future. The small closed state and the seedling/sapling open states are predicted to remain relative constant decreasing only slightly as they continue to develop into the larger state classes. The medium/large closed state is predicted to account for as much as 42 percent of the Madrean Encinal Woodlands land area in 100 years.

As the medium/large closed canopy state continues to increases, grass and forb production will decrease and shrub development will tends to increase. Patch size, which is currently within the historical range, may begin to increase in size as the canopies close in and canopy gaps become smaller. Coarse woody debris is predicted to increase and may contribute to increased risk of uncharacteristic wildfire.

Madrean Encinal Woodland (MEW)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A	Grass/Forb/Shrub	20	23	----	48	27	26	29	29	16
F	Small (closed)	40	11	----	11	12	15	12	12	11
B, E, C	Seedlings/Saplings and Small Trees (open)	25	14	----	11	11	5	10	10	8
D	Medium/Large (open)	15	24	----	16	17	11	16	16	22
G	Medium/Large (closed)	0	27	----	15	34	42	33	33	42
		Departure[3]:	40 (M)	----	44 (M)	42 (M)	48 (M)	43 (M)	43 (M)	50 (M)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See “Seral State Proportion” section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 0.7 to 50 acres. Current patch size = 30 acres. Departure is within the natural range of variation.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Graminoids: Increases in sideoats grama (*Bouteloua curtipendula*).

Shrubs and trees: Large decreases in alder-leaf mountain-mahogany (*Cercocarpus montanus*), pointleaf manzanita (*Arcostaphylos pungens*), and buckthorn (*Rhamnus spp.*), and slight increase in Wright’s silktassel (*Garrya wrightii*). Overall, pinyon pine (*Pinus edulis*) has increased in abundance, while Emory oak (*Quercus emoryi*) has decreased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Moderate (42%)	Moderate (38%)	Moderate (60%)	Moderate (57%)	**Low (33)**
Species present/potential Species	14/54	19/35	16/24	8/9	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 46 percent.

Current = 29 percent

Departure = Moderate (53)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 2.2 tons per acre. Snags greater than 8 inches = 4.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 21.3 tons per acre. Snags greater than 8 inches = 5.6. Snags greater than 18 inches = 0.8

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had non-lethal (mostly surface fires) to mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I). However some areas did experience mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III).

Fire current conditions: Fire return interval = 170 years

Fire severity: Non-lethal = 57 percent. Mixed = 38 percent. Stand-replacing = 5 percent

Fire regime condition class: Class I = 0 percent. Class II = 100 percent. Class III = 0 percent

Insect and disease: Surveyed yearly. No specific historic records of insects and pathogens. System is at low risk for effects.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: yellow starthistle (*Centaurea solstitialis*), fountain grass (*Pennisetum setaceum*), sweet resinbush (*Euryops subcarnosus*)
- Moderate: diffuse knapweed (*Centaurea diffusa*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

No acres of noxious weeds have been mapped in this ecological response unit.

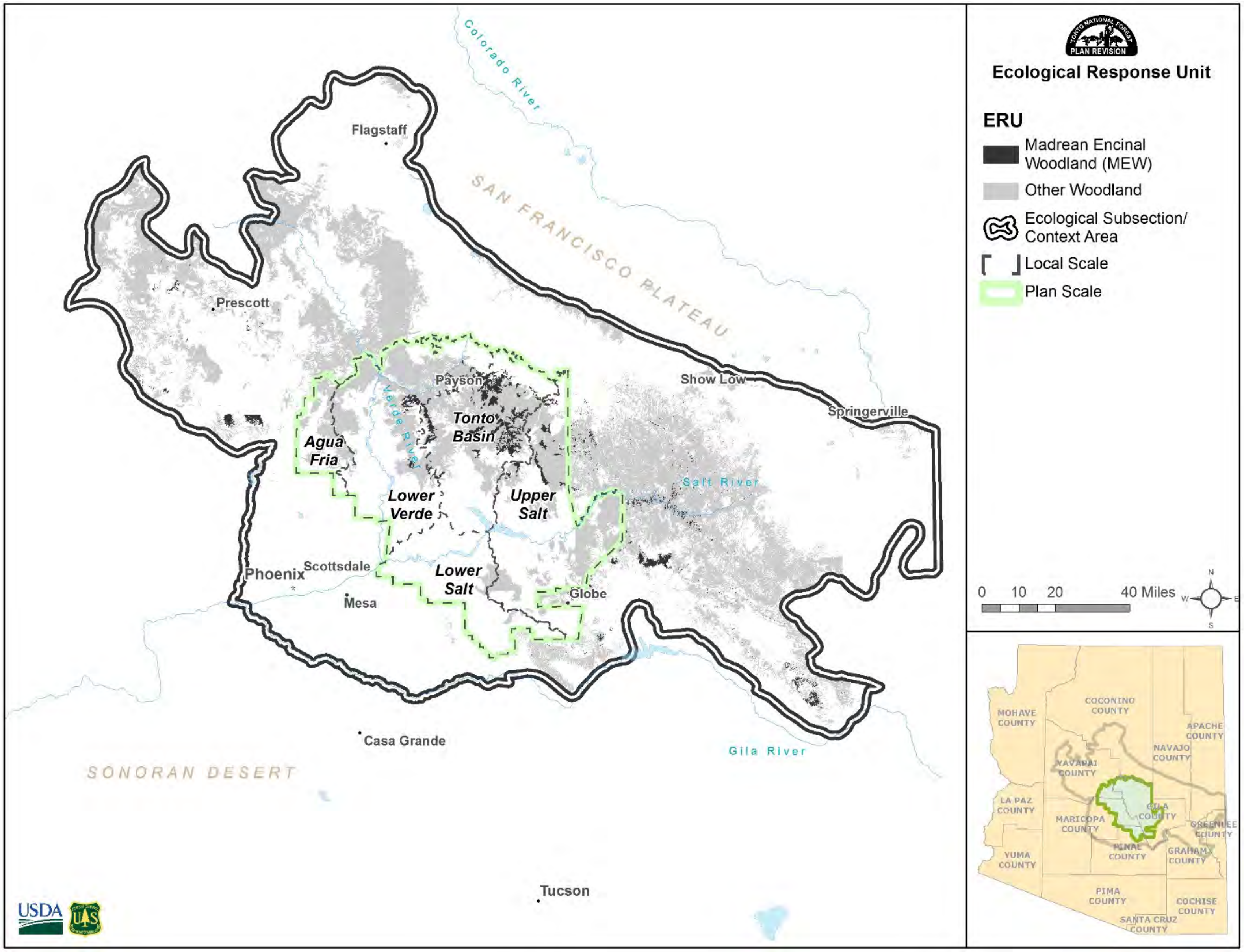


Figure 15. Madrean Encinal Woodland ecological response unit

Pinyon-Juniper Evergreen Shrub (PJC)

Elevation: 2,400 – 7,800 feet

Table 31. Distribution (acres and percent) at the context, plan, and local scales for Pinyon-Juniper Evergreen Shrub

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
1,875,546	398,154	8,719	90,131	133,208	151,777	14,319
15%	14%	5.1%	11.7%	21.5%	19.9%	3.3%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 32. Terrestrial ecosystem niche, Pinyon-Juniper Evergreen Shrub

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
21.2%	-0.04	Low

Photo 8. Pinyon-Juniper Evergreen Shrub

This ecological response unit is generally found on lower slopes bordering chaparral at lower elevations and montane forests at higher elevations. This type reaches dominance among areas with mild climate gradients and bi-modal precipitation regimes (Wahlberg et al. 2013). Dominant tree and shrub species include twoneedle pinyon (*Pinus edulis*), single leaf pinyon (*Pinus monophylla* var. *fallax*), Utah juniper (*Juniperus osteosperma*), oneseed juniper (*J.* monosperma), alligator juniper (*J. deppeana*), Manzanita spp. (*Arctostaphylos spp.*), mountain mahogany (*Cercocarpus montanus*), Antelope bushes (*Purshia spp.*), silktassles *(Garrya spp.*), Stansbury cliffrose (*Purshia stansburiana*), turbinella oak (*Quercus turbinella*), and sumacs (*Rhus spp*.). Pinyon may be absent at some areas, however juniper is always present. Oaks (Arizona white oak, grey oak, Emory oak) become more common among mild climate zones in central Arizona. The understory is dominated by low to moderate density shrubs, with herbaceous plants in the interspaces. This ecological response unit is found on well-drained soils, frequently with coarse-textured or gravelly (stony) soil characteristics. Aside from disparities in structure and composition, Pinyon-Juniper Evergreen Shrub can also be differentiated from Interior Chaparral by longer fire intervals and less severe fire events.

The Pinyon-Juniper Evergreen Shrub ecological response unit covers 398,154 acres on the Tonto National Forest and 1,875,546 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto (14 percent) is similar to the context area (15 percent). With a very low proportional representation on the Tonto (-0.04), the opportunity for the Tonto National Forest to influence context scale conditions for this ecological response unit is low. The Pinyon-Juniper Evergreen Shrub ecological response unit is present in all five local zones. Most acres are located in the Upper Salt (151,777 acres), Tonto Basin (133,208 acres), and Lower Verde zones (90,131 acres), with lesser amounts in the Lower Salt zone (14,319 acres) and the Agua Fria zone (8,719 acres).

Reference Conditions

Information on the historic condition of this type is sparse. Pinyon-Juniper Evergreen Shrub normally occurs as a mix of trees and shrubs with sparse herbaceous cover but can be characterized by a series of vegetation states that move from herbaceous-dominated to shrub-dominated to tree-dominated over time, unless interrupted by a high severity stand replacing fire or a mixed-severity fire. Mixed-severity fire returns severely-burned vegetation patches to an herbaceous-dominated state and reduces tree and shrub densities in less severely-burned vegetation patches.

Typical disturbances (fire, insects, and disease) are mixed severity and moderate, although some evergreen shrub woodland types exhibit infrequent fire/high severity effects (fire regime IV, 35-200 years, replacement severity; for example, pinyon-juniper manzanita). Disturbance patterns create and maintain tree-age diversity and low to moderately closed canopy that is typical of this type. Historically this ecological response unit had greater than 10 percent tree canopy cover in later successional stages. Trees occur as individuals or in smaller groups and range from young to old, but typically small stands or clumps are even-aged in structure as a consequence of mixed-severity fire. The shrubs understory ranges from low to moderate density depending on the time since the last disturbance. Shrub species include manzanita, mountain mahogany, antelope bushes, silktassles, Stansbury cliffrose, turbinella oak, and sumacs. Perennial native grasses and both annuals and perennial forbs comprise the remainder of the inter-canopy interspaces.

Current Conditions

Current conditions on the Tonto show a shift toward the medium/large closed canopy state with the shrub densities increasing and herbaceous plant cover decreasing. The early development, post disturbance grass/forb/shrub state exceeds reference condition and is currently at 38 percent. Conditions at the context scale are similar in nature to the conditions on the national forest, except the amount of departure is not as great (54 percent). At the context scale closed canopy states have increased in both the small and medium/large tree states while post disturbance grass/forb/shrub state has increased to 22 percent. All five local zones are showing a departure rating of high (72 percent or higher). Departure on the Upper Salt (77 percent), Tonto Basin (72 percent), and Lower Verde zone (75 percent) is similar to the departure found at the planning scale in both the types of departure and the amounts of departure. The Lower Salt and Agua Fria zones are showing a slightly higher level of departure and a large increase in the amounts of the grass/forb/shrub state. The Lower Salt zone has an ecological response unit departure rating of 84 percent, with 56 percent of the ecological response unit in the grass/forb/state and the Agua Fria zone has an ecological response unit departure rating of 86 percent with 80 percent of the ecological response unit in the grass/forb/state. The high percentage of the grass/forb/shrub state can be attributed to the 2005 Cave Creek Complex Fire in the Agua Fria zone, and several other fires which burned through this ecological response unit across the national forest with mixed to stand replacing intensity.

Fire suppression and grazing have both contributed to a lengthening of the fire return interval to 215 years instead of the 35 to 100+ years found under reference conditions. This has allowed the coarse woody debris to build up to 23.9 tons per acre and the number of snags greater than 8” to reach 5.6 per acre. This is good for providing wildlife habitat but is likely to increase fire behavior to the point where wildfires is more resistant to control. The in-filling of the canopy gaps and increased density of brush species in the medium/large closed state has led to a reduction in the abundance and diversity of grass and forb species. However, recent fires have helped to reduce patch size to 40 acres which is only slightly smaller than the reference condition of 50 to 200 acres.

Future Trend

The conditions in the Pinyon-Juniper Evergreen Shrub ecological response unit is projected to slowly improve, moving closer to reference conditions by the year 100. Vegetation Dynamics Development Tool models predict the amount of grass/forb/shrub state on the plan scale to decrease over time as seedlings and small trees become established. The small closed state and the seedling/sapling small tree open state will remain relatively constant with only minor fluctuations. The medium/large open state and the medium/large closed state are predicted to increase as tree diameter increase with the majority of the increase occurring in the medium/large open state. The medium/large open state is predicted to be near reference condition levels at 34 percent by the year 100. However, the medium/large closed state is expected to continue to increase, reaching 31 percent, a condition that was not found in the reference condition.

The medium/large closed canopy condition is the result of the in-filling of canopy gaps and increases in density of tree groups and brush species. As the canopy closes and the brush increases there is a corresponding reduction in the composition, density, and vigor of the herbaceous understory vegetation. Many of these closed canopy sites will have insufficient herbaceous vegetation to carry non-lethal surface fires. As a result, these closed canopy sites will continue to be stressed and the potential for insect, pathogens and wildfire will continue to be very high.

Pinyon-Juniper Evergreen Shrub (PJC)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[1] (100 years)**
A	Grass/Forb/Shrub	5	22	80	41	34	36	56	38	11
B, E, C	Small (closed)	0	12	4	9	9	8	7	14	12
F	Seedlings/Saplings and Small Trees (open)	55	9	3	16	14	14	13	9	12
D	Medium/Large (open)	40	29	5	10	14	10	4	11	34
G	Medium/Large (closed)	0	29	9	23	29	33	20	28	31
		Departure[2]:	54 (M)	86 (H)	75 (H)	72 (H)	77 (H)	84 (H)	76 (H)	49 (M)

1. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale), see "Seral State Proportion" section for more information.
2. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See "Seral State Proportion" section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 50 to 200 acres. Current patch size = 40 acres. Departure = low, slightly smaller.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: native buckwheat (*Erogonum spp.*) have increased in abundance.

Graminoids: Large increases in hairy and curlymesquite grass (*Bouteloua hirsuta* and *Hilaria belangeri*) and slight decreases in desert needlegrass (*Achnatherum speciosum*).

Shrubs and trees: catclaw acacia (*Acacia greggii*), broom snakeweed (*Gutierrezia sarothrae*), and Sonoran scrub oak (*Quercus turbinella*) have all increased in abundance, while pointleaf manzanita (*Arcostaphylos pungens*) has decreased overall. A general shift in abundance from single-leaf pinyon (*Pinus monophylla*) to one-seed juniper (*Juniperus osteosperma*).

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (12%)	Low (28%)	Moderate (38%)	Low (39%)	**Low (21)**
Species present/potential Species	22/91	33/56	40/61	11/14	

1. Forbs include all herbaceous flowering plants. 2. Graminoids include all grasses, sedges, and rushes.

Vegetative Ground Cover (plan scale)

Reference = 62 percent

Current = 31 percent

Departure = Moderate (39)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 3.0 tons per acre. Snags greater than 8 inches = 3.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 23.9 tons per acre. Snags greater than 8 inches = 5.6. Snags greater than 18 inches = 1.3

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III). However some areas did experience high-severity, stand-replacing fires where greater than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime IV).

Fire current conditions: Fire return interval = 215 years

Fire severity: Non-lethal = 57 percent. Mixed = 25 percent Stand-replacing = 18 percent

Fire regime condition class: Class I = 21 percent. Class II = 79 percent. Class III = 0 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed. A survey in 2003 showed an unprecedented, severe outbreak of pinyon bark beetles.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: Russian knapweed (*Acroptilon repens*), sweet resinbush (*Euryops subcarnosus*)
- Moderate: Malta starthistle (*Centaurea melitensis*), Dalmatian toadflax (*Linaria dalmatica*), diffuse knapweed (*Centaurea diffusa*), yellow starthistle (*Centaurea solstitialis*)
- Low: jointed goatgrass (*Aegilops cylindrical*)

Seven acres of noxious weeds have been mapped in this ecological response unit.

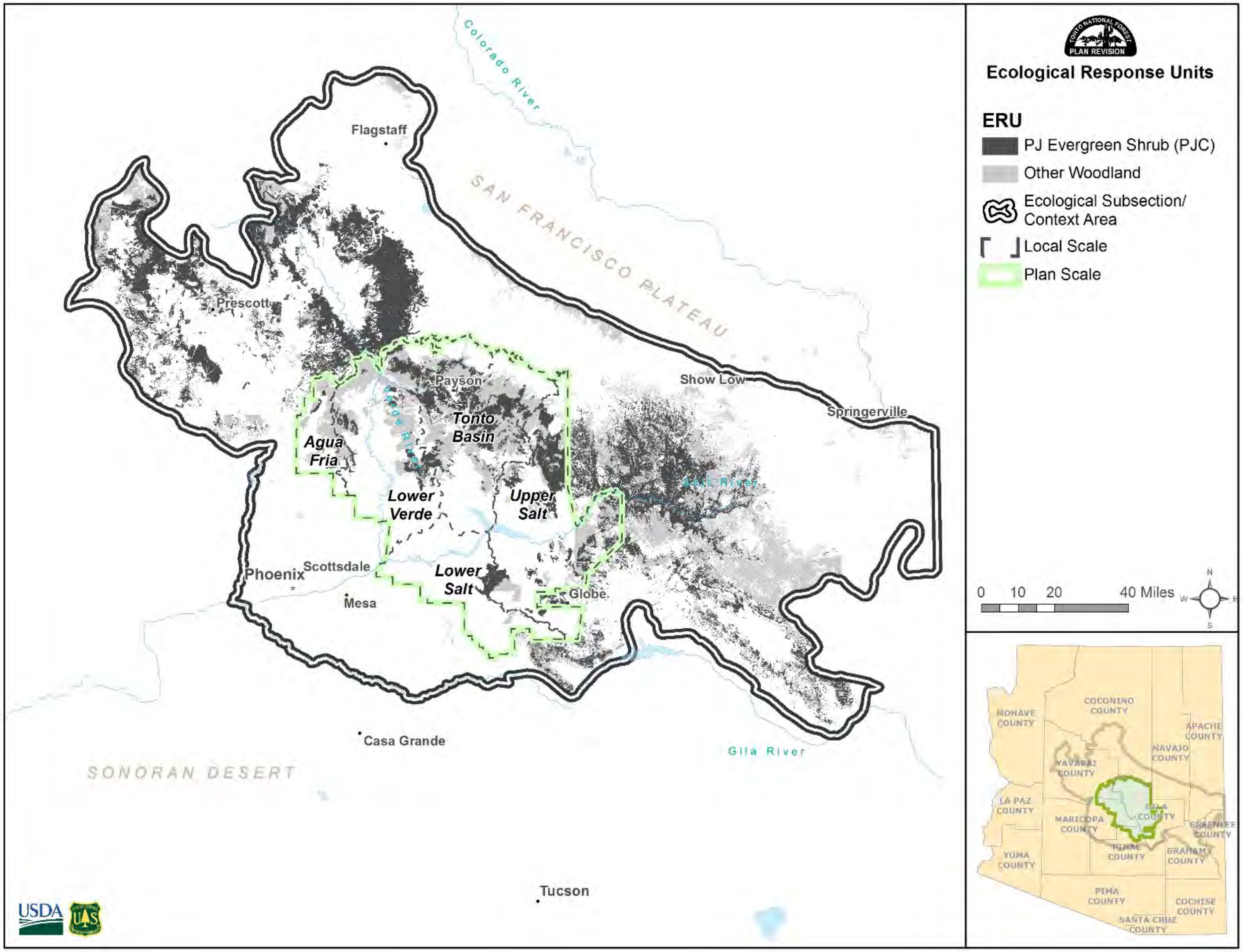


Figure 16. Pinyon-Juniper Evergreen Shrub ecological response unit

Pinyon-Juniper Grass (PJG)

Elevation: 3,400 – 7,000

Table 33. Distribution (acres and percent) at the context, plan, and local scales for Pinyon-Juniper Grass

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
612,017	74,240	720	8,180	33,728	31,612	
5%	3%	0.4%	1.1%	5.4%	4.1%	

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 34. Terrestrial ecosystem niche, Pinyon-Juniper Grass

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
12.1%	-0.31	Low

Photo 9. Pinyon-Juniper Grass

The Pinyon-Juniper Grass ecological response unit occurs across the states of Arizona and New Mexico, in what were historically more open woodlands with grassy understories. Tree species include one seed juniper (*Juniperus monosperma*), Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*Juniperus scopulorum*), alligator juniper (*Juniperus deppeana*) and twoneedle pinyon (*Pinus edulis*). Native understories were made up of perennial grasses, with both annual and perennial forbs, and shrubs that were absent or scattered. Loamy soils, warm summers, and bimodal precipitation are typical for Pinyon-Juniper Grass types (Wahlberg et al. 2013).

Historically, herbaceous understories of native grasses and forbs provided fine fuel sources for fire, aiding in the maintenance of an uneven-aged open canopy condition (Wahlberg et al. 2013).

The Pinyon-Juniper Grass ecological response unit covers 74,240 acres on the Tonto National Forest and 612,017 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto is 3 percent, similar to the context area representation of 5 percent. With a low proportional representation on the Tonto (-0.31), the opportunity for the Tonto National Forest to influence context scale conditions for this ecological response unit is low. At the local scale, most acres are located in the Tonto Basin (33,728 acres) and Upper Salt zones (31,612 acres) with lesser amounts in the Lower Verde zone (8,180 acres) and minor amounts in the Agua Fria zone (720 acres).

Reference Conditions

Information on the historic condition of this type is sparse. The Pinyon-Juniper Grass type historically occurred across the Southwest, with trees that would have occurred as individuals or in smaller clumps and ranged from young to old (uneven-aged) open woodlands with grassy understories (Ffolliott and Gottfried 2002). Scattered shrubs and a dense herbaceous understory of native perennial grasses and annual and perennial forbs characterize this type. Site productivity suggests that the development of a grass and fine fuels layer (22 percent groundcover) would have supported frequent-fire, open-forest dynamics (Gottfried 2003). Typical disturbances (fire, insects, and disease) were of low severity and high frequency, creating and maintaining an uneven-aged open canopy. The historic fire return interval was 8 to 36 years (Margolis 2014; Basin and Swetnam 1995; Grissino-Mayer and Swetnam 1995; Allen 1989) from low to moderate severity fire. Reference patch sizes in this system averaged 1 acre and had less amounts of coarse woody debris (3.5 tons per acre) than other woodlands.

Current Conditions

Fire exclusion and a history of grazing have favored closed canopy structures susceptible to drought or insect induced mortality. This has resulted in a moderate departure from reference conditions at the context and planning scales. Medium to large tree, open canopies have been replaced with typical in-filling of the canopy gaps, increased density of small tree groups; which reduce composition, density and vigor. Current conditions on the Tonto indicate a shift in canopy cover toward the more closed canopy states with the medium/large closed state increasing from the 10 percent found in reference conditions to 23 percent. At the context scale, the shift to medium/large tree state with a closed canopy is more pronounced with 52 percent of the context scale acreage in this medium/large closed state. Range improvements, fuelwood harvest, and fire (prescribed fire and wildfire) have moved some acres on the national forest from the medium/large closed state to the grass/forb/shrub and seedling/sapling and small tree open states. The grass/forb/shrub state on the Tonto is now at 24 percent and the seedling/sapling small tree state is at 19 percent. At the context scale, the grass/forb/shrub state remains at 5 percent and the seedling/sapling small tree state is at 9 percent. The small closed state is at or near reference conditions with the national forest currently at 13 percent and the context scale at 10 percent. At the local zones, the Tonto Basin and Upper Salt are similar to the planning scale in the level and type of departure, with moderate departures of 35 percent and 40 percent respectfully. The Lower Verde and the Agua Fria zones are also showing moderate departures of 38 percent and 35 percent, but the type of departure is somewhat different. The Lower Verde and Agua Fria zones have less in the medium/large closed state (18 percent and 17 percent), but more in the earlier developmental states. The Lower Verde zone has 24 percent in the small closed state and 40 percent in the seedling/sapling and small tree state. The Agua Fria zone shows 17 percent in the grass/forb/shrub state and 39 percent in the seedling/sapling and small tree state. This can be attributed to the 2004 Willow Fire in the Lower Verde zone and the 2005 Cave Creek Complex Fire, both of which burned through this ecological response unit with mixed to stand-replacing intensity.

Fire exclusion, range management activities, and grazing have all contributed to increases in patch size averaging nearly 19 acres at the plan scale, which is highly departed from the small patch sizes of 1 acre or less found in the reference condition. An increase in coarse woody debris, a decrease in ground cover, and a reduction in the diversity of grass, forbs, and shrubs are a result of the in-filling of the canopy gaps and increased density. These conditions are all very interrelated to fire severity and function. Historically, these system burned under a frequent non-lethal fire regime with a fire interval of 0-35 years. Now they are experiencing fire return intervals of up to 215 years with 29 percent of these fires burning with mixed severity and 29 percent burning with stand-replacing intensity. Many of these sites have uncharacteristically high shrub cover and insufficient ground vegetation to carry non-lethal surface fire. All these changes combined have stressed this system and increased the potential for bark beetle activity above what would have been expected in pre-settlement conditions and contribute to greater tree mortality when outbreaks similar to the pinyon bark beetle outbreak of 2003 occur.

Future Trend

Vegetation Dynamics Development Tool models predict the amount of grass/forb/shrub state on the plan scale to decrease to near reference condition levels by the year 67. The small closed state and the seedling/sapling small tree open state will remain relatively constant with a slight decrease in the seedling/sapling small tree open state. The medium/large open state and the medium/large closed state are predicted to increase as tree diameter increase with the majority of the increase occurring in the medium/large open state. The medium/large open state is predicted to be near 36 percent by year 100, still well below the 50 percent found in the reference condition. The medium/large closed state is expected to reach 34 percent, a condition that accounted for only 10 percent in the reference condition.

Management has created and maintained a higher proportions of the Pinyon-Juniper Grass in the grass/forb/shrub state. This has put this ecological response unit on a trajectory that in the future will bring it closer to reference conditions with a predicted departure at 100 years of 27 percent (low). With continued fire suppression and livestock grazing the small closed state and some of the medium/large open state will continue to move into the medium closed state as the in-filling of the canopy gaps continues. Thirty-four percent of this ecological response unit will remain in a denser state and continue to be increasingly susceptible to outbreaks of insects, pathogens, and stand-replacing wildfire.

Pinyon-Juniper Grass (PJG)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A	Grass/Forb/Shrub	5	5	17	7	28	25	----	24	4
F	Small (closed)	10	10	10	24	9	14	----	13	13
B,E,C	Seedlings/Saplings and Small Trees (open)	25	9	39	40	17	14	----	19	13
D	Medium/Large (open)	50	25	15	12	23	21	----	21	36
G	Medium/Large (closed)	10	52	18	17	22	26	----	23	13
		Departure[3]:	42 (M)	35 (M)	38 (M)	35 (M)	40 (M)	----	35 (M)	27 (L)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See “Seral State Proportion” section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 0.07 to 1 acres. Current patch size = 19 acres. Departure = high, much larger

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: broom snakeweed (*Gutierrezia sarothrae*) and slimflower scurfpea (*Psoralidium tenuiflorum*) have increased in abundance, while wooly plantain (*Plantago patagonica*) has decreased in abundance.

Graminoids: Large decreases in hairy and curlymesquite grass (*Bouteloua hirsuta* and *Hilaria belangeri*), and slight increases in sideoats grama (*Bouteloua curtipendula*).

Shrubs and trees: Overall there has been a shift in abundance from pointleaf manzanita (*Arcostaphylos pungens*) to catclaw mimosa (*Mimosa aculeaticarpa*). Alligator juniper and single-leaf pinyon (*Juniperus deppeana* and *Pinus monophylla*) have increased at some locations, while one-seed juniper has decreased at others.

Lifeform	**Forbs[1]**	**Graminoids[2]**	**Shrubs**	**Trees**	**All lifeforms (overall)**
Similarity to site potential (plan scale)	Moderate (35%)	Moderate (44%)	Low (22%)	Low (32%)	**Low (28)**
Species present/potential Species	44/116	35/55	29/41	10/10	

1. Forbs include all herbaceous flowering plants. 2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 36 percent

Current = 16 percent

Departure = Moderate (49)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 3.5 tons per acre. Snags greater than 8 inches = 5.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 14.6 tons per acre. Snags greater than 8 inches = 5.7. Snags greater than 18 inches = 0.9

Ecosystem Drivers and Stressors

Fire reference conditions: The fire regime for this ecological response unit is defined as having non-lethal (mostly surface fires) to mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I).

Fire current conditions: Fire return interval = 215 years

Fire severity: Non-lethal = 42 percent. Mixed = 29 percent. Stand-replacing = 29 percent

Fire regime condition class: Class I = 0 percent. Class II = 100 percent. Class III = 0 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed. A survey in 2003 showed an unprecedented, severe outbreak of pinyon bark beetles.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- High: yellow starthistle (*Centaurea solstitialis*)
- Moderate: Canada thistle (*Cirsium arvense*)
- Low: jointed goatgrass (*Aegilops cylindrical)*

Six acres of noxious weeds have been mapped in this ecological response unit.

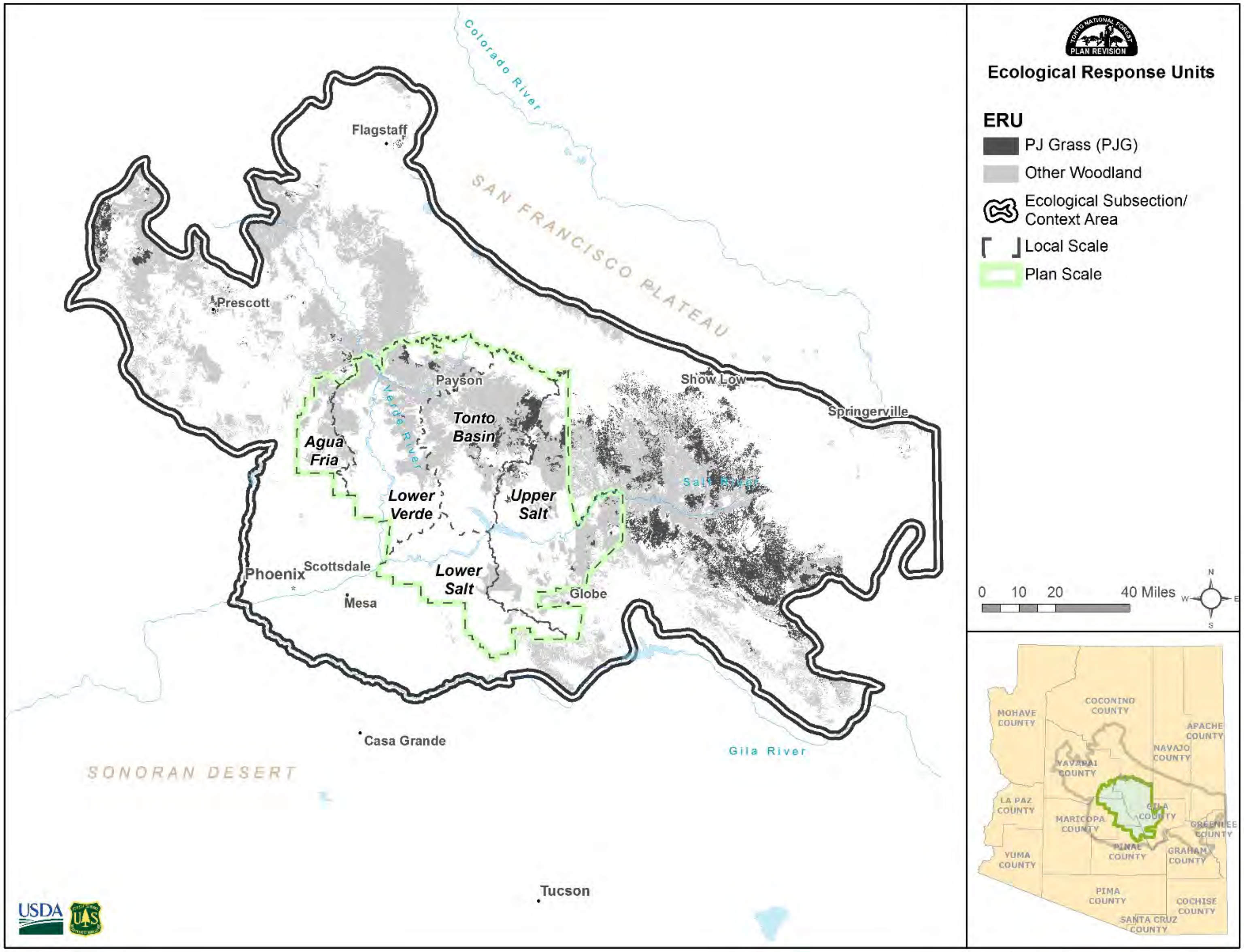


Figure 17. Pinyon-Juniper Grass ecological response unit

Ponderosa Pine - Evergreen Oak (PPE)

Elevation: 5,500 – 7,200 feet

Table 35. Distribution (acres and percent) at the context, plan, and local scales for Ponderosa Pine - Evergreen Oak

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
532,841	205,729	63	68,396	70,885	62,835	3,550
4%	7%		8.9%	11.4%	8.2%	0.8%

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 36. Terrestrial ecosystem niche, Ponderosa Pine - Evergreen Oak

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
38.6%	0.26	High

Photo 10. Ponderosa Pine - Evergreen Oak

The Ponderosa Pine - Evergreen Oak ecological response unit occurs in the mild climate gradients of central and southern Arizona and in southern New Mexico, particularly below the Mogollon Rim, where warm summer seasons and bimodal (winter-summer) precipitation regimes are characteristic. This type occurs at elevations ranging from 5,500 to 7,200 feet, on sites slightly cooler-moister than the Madrean Pinyon-Oak ecological response unit, and with a much greater plurality of ponderosa pine. This system is dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum*) and can be distinguished from the Ponderosa Pine Forest ecological response unit by well-represented evergreen oaks (for example, Emory oak, *Quercus emoryi*), Arizona white oak (*Quercus arizonica*), alligator juniper, and pinyon pine (for example, *Pinus edulis*). In some areas, Ponderosa Pine - Evergreen Oak communities can alternatively be dominated or codominated by Apache pine (*Pinus englemannii*) and Chihuahuan pine (*P. leiophylla*), both site potential indicators. In terms of disturbance, the Ponderosa Pine - Evergreen Oak averaged greater fire severity than the ponderosa pine forests above the Mogollon Rim, and greater patchiness with less horizontal uniformity and more even-aged conditions. Understory shrubs include manzanita (*Arctostaphylos* sp.), turbinella oak (*Quercus turbinella*), skunkbush sumac (*Rhus trilobata*), and mountain mahogany (*Cercocarpus montanus*). Depending on site conditions, shrubs and perennial grasses have varying importance in vegetation response to disturbance. Historically this ecological response unit had over 10 percent tree canopy cover, with the exception of early, post-fire plant communities.

The Ponderosa Pine - Evergreen Oak ecological response unit covers 205,729 acres on the Tonto National Forest and 532,841 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto is 7 percent of the land area, slightly higher than the context area representation of 4 percent. This high proportional representation on the national forest means the sustainability of this system at the context scale is highly sensitive to conditions on the planning scale. The Ponderosa - Evergreen Oak occurs to some extent in all five of the local zones. The majority (98 percent) is fairly well distributed in the Lower Verde, Tonto Basin, and Upper Salt zones. A small amount can be found in the Lower Salt zone (3,550 acres) with only a minor amount (63 acres) located in the Agua Fria zone.

Reference Conditions

Currently Ponderosa Pine - Evergreen Oak can be split into two provisional subclasses that describe historical structure of this system: Ponderosa Pine - Evergreen Oak, Perennial Grass subclass and Ponderosa Pine - Evergreen Oak, Evergreen Shrub subclass.

The Perennial Grass subclass is distinguished from the Evergreen Shrub subclass by a more continuous layer of perennial grasses in the understory and a relatively minor shrub component. These circumstances may be less evident in the current condition depending on the degree of shrub encroachment. Trees occur as individuals or in smaller groups and range from young to old but were historically more uneven-aged in structure. The understory is dominated by low to moderate density shrubs, with herbaceous plants in the interspaces. Common grass species include Arizona fescue (*Festuca arizonica*), a variety of muhleys (for example, *Muhlenbergia longiligula, M. dubia, M. straminea, and M. montanum*). Fire frequency varied but averaged higher with less severity. These disturbance patterns create and maintain the uneven-aged (grouped), low- to moderately-closed canopy nature of this type. Site potential and disturbance history also maintained oak, juniper, and pinyon as subdominant tree components, with herbaceous plants in the interspaces.

The Evergreen Shrub subclass differs from the former subclass by site potential, typically favoring high shrub cover, and by higher fire severity and more even-aged conditions characteristic of mixed-severity fire regimes. This type is found on well-drained soils, frequently with coarse-textured or gravelly (stony) soil characteristics that favor shrub layer development (particularly oaks) over herbaceous plants. Trees occur as individuals or in small groups and patches and range from young to old, but typically groups or patches are even-aged in structure. The understory is dominated by moderate- to high-density shrubs, with limited grass cover. Typical disturbances (fire, insects, and disease) worked collectively to favor mixed-severity conditions (fire regime III, where sufficient tree canopy provides needle-cast to facilitate fire spread). Some high-density evergreen shrub patches exhibit infrequent, high severity fire (fire regime IV; stand replacement at 35-200 years). Areas where this pattern was persistent are likely to be mapped as Interior Chaparral ecological response unit. More typical disturbance patterns created and maintained the even-aged tree groups, with a moderate to moderately-closed canopy.

The Ponderosa Pine - Evergreen Oak ecological response unit supported a range of fire regimes. In systems supporting a predominantly grass understory, fire regime group I historically burned frequently with low intensity fire. In systems supporting a more robust shrub component, the fire regime group III historically burned with mixed severity. These fires maintained this ecological response unit in a predominantly open state with 60 percent in the medium/large open state and 24 percent in the small open state. The range in fire regimes also resulted in a range of patch sizes, with mixed-severity fires creating larger patch sizes while the frequent non-lethal fire areas contained smaller patch sizes. Reference condition patch sizes ranged from 0.2 acres to 50 acres in size depending on the intensity of fire that occurred with higher intensity fires creating the larger patches. Frequent fires also prevented the buildup of coarse woody debris, maintaining an average of 3.8 tons per acre, and prevented the brushy understories and the juniper and oaks from becoming well established.

Current Conditions

Due to the effects of long-term fire suppression and grazing in this type, in many locations the current condition is highly departed from historic conditions. Typically these changes include in-filling of the canopy gaps, increased density of tree groups; and reduced composition, density and vigor of the herbaceous understory plants. Other significant changes resultant from fire exclusion are increased homogeneity of the shrub structural stages on the landscape, facilitating larger patch sizes of high-severity fire effects. Currently, many of these sites are closed-canopy forests, capable of supporting crown fires.

Current conditions on the Tonto and the context scale show a distinct shift toward the medium/large closed canopy state class with deficiencies in the medium/large and small open canopy state classes. The medium/large closed state has increased to 64 percent on the national forest and 55 percent at the context scale. The open medium/large state has decreased to 8 percent on the Tonto and 12 percent at the context scale, much lower than the 60 percent in the medium/large open state that would be expected in the reference condition. Without fire to thin the smaller trees, the small closed state has increased to 13 percent on the national forest and 19 percent at the context scale, while the small open state has decreased to 7 percent on the Tonto and 6 percent at the context scale. The seedling/sapling state class is also underrepresented, occupying only 1 percent of the ecological response unit acreage on the Tonto, and the seedling/sapling state class is virtually nonexistent at the context scale. The Lower Verde, Tonto Basin, and Upper Salt zones all have similar high departure ratings. These three zones show very similar conditions to the plan and context scale departure, with an increases in the medium/large and small closed states and a corresponding decrease in the medium/large and small open states. The Lower Salt zone shows a slightly lower departure rating of moderate, due to lower amounts of the seral state proportion in the medium/large closed state (28 percent) and a slightly larger percentage than the other zones in the small open state (17 percent). The grass/forb/shrub state within this zone also accounts for 23 percent of the ecological response unit and can be attributed to several fires that have occurred within this zone. The 1970 Solder Fire, 1996 Lone Fire, 2000 Peak Fire, and the 2005 Four Fire all burned through the Ponderosa Pine - Evergreen Oak in this zone.

Fuel continuity has increased dramatically in Ponderosa Pine - Evergreen Oak, as open spaces fill in horizontally and vertically, resulting in higher burn severities from wildfire. Twenty-seven percent of the Ponderosa Pine - Evergreen Oak on the Tonto has burned with mixed severity, while 16 percent has burned with high severity. Current mean fire return interval is now at 115 years compared to 0-35 years that was common in reference conditions.

Fire exclusion, historic grazing, and past selective logging practices have resulted in a lack of open canopy, larger patch sizes, less groundcover, increased coarse woody debris, and understories that are now dominated by moderate- to high-density shrubs, with limited grass cover. Patch size has increased from reference conditions of 0.2 to 50 acres to a mean of 150 acres, and there has been a general loss of grass and forbs accompanied by a loss of plant diversity. This loss of diverse ground vegetation also effects the ability to re-introduce surface fire following mechanical treatments or as a prescribed fire, because there is not enough fuel (grass and forb cover) to carry low-intensity ground fire. While coarse woody debris and snags are well distributed through the ecological response unit and provides adequate resources for wildlife benefits, coarse woody debris has built up to levels in the mid to late seral stages (37.1 tons per acre) that are high enough to increase the risk of soil loss (from heating) following a wildfire. Some tree species (juniper and oak) and understory shrubs (manzanita and turbinella oak) that were historically held in check due to frequent fire have now become well established, adding to the current fuel ladder and fuel loading.

Future Trend

Vegetation Dynamics Development Tool modeling predicts a gradual decrease in the closed states and a corresponding increase in the open states under current management. The small closed state is predicted to decrease form 13 percent to 6 percent, and the medium/large closed state is predicted to decrease from 64 percent to 24 percent. The small open state is predicted to increase to 11 percent, and the medium/large open states is predicted to increase to 34 percent. Even with the predicted improvement, this ecological response unit will remain moderately departed after 100 years under current management.

Current management is beginning to move the state class distributions toward the reference conditions. As stands are treated either mechanically or by prescribed fire, stands are opened up and patch size is reduced. Brush species and oak and juniper sprouts are kept at manageable levels freeing up space for increased grass and forb production. Coarse woody debris and snags are maintained within historic conditions reducing the risk of uncharacteristic wildfire. Until closed stands are treated, they remain at risk to wildfire. Increasing the pace of treatments can reduce time required to achieve more resilient and resistant conditions.

Ponderosa Pine - Evergreen Oak (PPE)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A	Grass/Forb/Shrub	4	8	----	6	9	4	23	7	6
B	Small (closed)	3	19	----	12	11	15	17	13	6
C	Small (open)	24	6	----	11	5	3	17	7	11
D	Medium/Large (open)	60	12	----	9	8	5	12	8	34
E	Medium/Large (closed)	4	55	----	61	64	70	28	64	24
F	Seedlings/Saplings	5	0	----	1	2	2	3	1	18
		Departure[3]:	71 (H)	----	68 (H)	74 (H)	79 (H)	56 (M)	73 (H)	39 (M)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See "Seral State Proportion" section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See "Seral State Proportion" section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 0.2 to 50 acres. Current patch size = 150 acres. Departure = high, much larger.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Large decreases in common yarrow (*Achillea millefolium*) and slight increase in native buckwheat (*Eriogonum spp*.).

Graminoids: Weeping lovegrass (*Eragrostis curvula*) has increased, while long-tongue muhly (*Muhlenbergia longiligula*) has decreased.

Shrubs and trees: Many shrubs have increased in abundance such as pointleaf manzanita (*Arcostaphylos pungens*) and broom snakeweed (*Guiterrezia sarothrae*), while many trees have decreased in abundance such as alligator juniper (*Juniperus deppeana*) and ponderosa pine (*Pinus ponderosa*).

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (30%)	Moderate (41%)	Moderate (34%)	Moderate (56%)	**Low (32)**
Species present/potential Species	21/97	21/37	27/37	10/13	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 97 percent

Current = 60 percent

Departure = Low (31)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See "Vegetative Groundcover" section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 3.8 tons per acre. Snags greater than 8 inches = 6.0. Snags greater than 18 inches = 1.0

Current: Coarse woody debris = 37.1 tons per acre. Snags greater than 8 inches = 8.7. Snags greater than 18 inches = 1.6

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had non-lethal (mostly surface fires) to mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I). However some areas did experience mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III).

Fire current conditions: Fire return interval = 115 years

Fire severity: Non-lethal = 57 percent. Mixed = 27 percent. Stand replacing = 16 percent

Fire regime condition class: Class I = 0 percent. Class II = 54 percent. Class III = 46 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed. Highly stressed stands led to unprecedented, severe outbreaks of bark beetles (occurred in the 2000s).

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- Moderate: yellow starthistle (*Centaurea solstitialis*)
- Low: bull thistle (*Cirsium vulgare*), jointed goatgrass (*Aegilops cylindrical*), Scotch thistle (*Onopordum acanthium*)

Six acres of noxious weeds have been mapped in this ecological response unit.

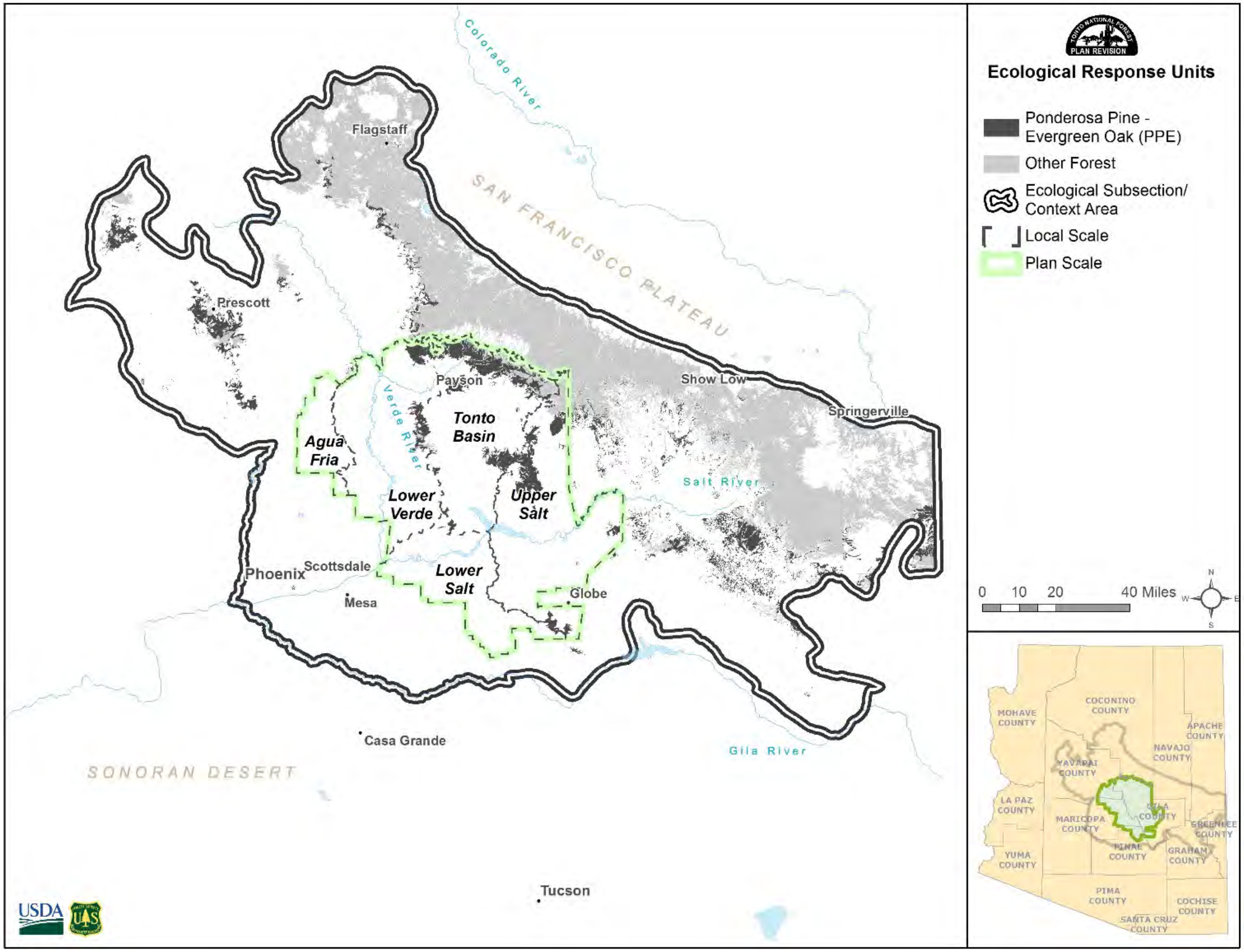


Figure 18. Ponderosa Pine - Evergreen Oak ecological response unit

Ponderosa Pine Forest (PPF)

Elevation: 5,500 – 7,600 feet

Table 37. Distribution (acres and percent) at the context, plan, and local scales for Ponderosa Pine Forest

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
2,137,070	37,878			13,966	23,912	
18%	1%			2.3%	3.1%	

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 38. Terrestrial ecosystem niche, Ponderosa Pine Forest

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
1.8%	-0.86	Low

Photo 11. Ponderosa Pine Forest

The Ponderosa Pine Forest ecosystem is widespread in the Southwest occurring at elevations ranging from 6,000 to 7,500 feet on igneous, metamorphic, and sedimentary parent soils with good aeration and drainage, and across elevation and moisture gradients. The dominant species in this system is ponderosa pine. Other trees, such as Gambel oak, pinyon pine, one-seed juniper, and Rocky Mountain juniper, 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. A historical fire regime of frequent, low-severity surface fires is widely documented, but there is growing evidence of limited scale areas of historical mixed-severity and high-severity fires, especially for steep slopes in areas of heterogeneous topography (Williams and Baker 2012; Swetnam et al. 2001; Iniguez et al. 2009).

The Ponderosa Pine Forest ecological response unit covers 37,878 acres on the Tonto National Forest and 2,137,070 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto is 1 percent of the land area, much lower than the representation on the context area of 18 percent. It is typically bounded down slope by the Ponderosa Pine - Evergreen Oak ecological response unit and upslope by Mixed Conifer Frequent Fire ecological response unit. The Ponderosa Pine Forest occurs in both the Tonto Basin zone and the Upper Salt zone along the northeastern boarder of the national forest. Most of acres are located in the Upper Salt zone (23,912 acres) with the remaining 13,966 acres in the Tonto Basin zone. With such a low proportional representation on the Tonto, the opportunity for the Tonto National Forest to influence context scale conditions for this ecological response unit is low.

Reference Conditions

Historical structure of southwestern ponderosa pine forest is characterized by multi-storied, open-canopy stands of medium to large trees with a well-developed, often grass-dominated understory (Covington and Sackett 1986). Overstory cover ranged from roughly 17 to 22 percent (White 1985; Covington and Sackett 1986; Covington et al. 1997). Climate had and still has a significant influence both directly and indirectly in shaping ponderosa pine landscapes. Site moisture availability directly effects tree recruitment. Indirectly, climate drives succession through influences on disturbances such as fire and insects. Successional patterns are also influenced by site elevation, proximity to seed sources, and pre-fire stand composition (Savage and Mast 2005), especially where sprouting species were present. Findings show broad pulses of recruitment separated by periods of less regeneration (Mast and Veblen 1999) where persistence of open grassy patches contrasts with canopy gap dynamics in which gaps would continuously form and close in different locations over decadal time spans.

Moreover, the open structure of historical stands of multi-storied medium to large trees resulted in a generally warm, dry microenvironment on the forest floor that kept fuel moisture very low, facilitating the ignition and spread of surface fires (Harrington and Sackett 1992). The historic average fire return interval was 4–30 years from low-severity fire (Swetnam and Dietrich 1985; O'Connor et al. 2014; Baisan and Swetnam 1990). Ponderosa pine is well-adapted to fire, with deep roots, fire resistant bark, self-pruned lower branches, branches and cones distant from the ground, open arrangement of branches and needles unfavorable to spread of fire, needles with high moisture content, thick bud scales, and longevity of seed production (Covington 2003). These enable trees to survive and regenerate in the presence of frequent surface fires. Frequent fires reflect the typical dry climate of the Southwest in that the annual inputs of organic matter (coarse woody debris, litter, and duff) accumulate because of slow decomposition rates, and these fuels are often sufficiently dry to carry fire. Historical coarse woody debris loadings averaged 9.0 tons per acre.

Years with abundant surface fire are correlated with drought, especially when preceded by 1 to 3 years of high precipitation during which herbaceous fine fuels increased (Swetnam and Baisan 1996; Touchan et al. 1996; Allen 2007; Allen et al. 2008; Margolis and Balmat 2009) and represented roughly 13 percent of groundcover. However, regeneration pulses also can be associated with fire and drought, which can be associated with overstory mortality and release of resources. Tree groups can vary greatly in size but in the Southwest, are generally 0.02 to 1.07 acres, with some as large as 2 acres (White 1985; Kaufmann et al. 2007).

Bark beetles are important disturbance agents in Ponderosa Pine Forest. Bark beetles affect stand structure and possibly were important historically in maintaining low tree densities, especially following surface fire and drought (Allen 1989). Bark beetles typically attack scattered, small clusters of trees, but larger outbreaks also occur. Another biotic disturbance agent is ponderosa pine dwarf mistletoe, a parasite plant that infects approximately one-third of the area of Ponderosa Pine Forest in Arizona and New Mexico (Andrews and Daniels 1960).

Current Conditions

Fire management throughout most of the twentieth century focused on preventing and suppressing fires. This continued the exclusion of surface fires that was initiated by livestock grazing. Just as southwestern Ponderosa Pine Forest was profoundly shaped by fire (Romme et al. 2009), it has also profoundly been altered by the exclusion of fire. Without frequent fires, southwestern Ponderosa Pine Forest increased in tree density, fuel loadings, and horizontal and vertical fuel continuities across landscapes, which has led to increased frequency and size of crown fires (Fulé et al. 2004; Romme et al. 2009). Shifts in climate could be related to this change in fire behavior, but increased fuel (for example, stand density and coarse woody debris) and canopy cover (for example, less patchiness, increased horizontal continuity) are the principal causes, based on observations of lower fire severity in sites less changed by fire exclusion (Stephens and Fulé 2005). Other factors, such as livestock grazing, wildlife population dynamics, tree cutting, and climate fluctuations, likely also intensified the problem by reducing vegetative ground cover that once carried frequent low-severity fire through Ponderosa Pine Forest stands. Fire management practices began to shift focus in the late 20th century to include the use of naturally ignited wildfires and prescribed fires to achieve resource management objectives. This has successfully changed fire behavior in these areas by reducing fuel loads and fuel continuity both vertically (ladder fuels) and horizontally (ability for fire to move from tree crown to crown). However, the area affected by prescribed fires has been small and tree densities, fuel loadings, and fuel continuity continue to result in landscape-scale crown fires in many areas.

When density changes are examined by diameter class, it is clear that diameter distributions have changed, with increases in smaller classes (23 percent increase) (Covington et al. 1997; Fulé et al. 1997, 2002) and in some cases decreases in larger classes. The overall increases in density (60 percent in closed states) and greater homogenization of diameter classes among stands have decreased structural diversity of stands and landscapes (Allen et al. 2002). With the increased density of small trees, tree growth rates decline in all diameter classes, with increased shade and root competition and decreased moisture and nutrients because of thicker litter (Harrington and Sackett 1990). It appears that reduced vigor is especially damaging to older, larger trees. Elevated mortality rates have been related to older trees being more susceptible to pathogens, drought, and injury because of increased stress through increased competition (Kaufmann and Covington 2001). Impediments to recovery of sustainable Ponderosa Pine Forest include competition with sprouting species such as juniper, oaks, New Mexico locust, and grasses, long distance to seed sources of ponderosa pine, and modern climate change toward higher temperatures and drier conditions (Fulé et al. 2012).

Ponderosa Pine Forest is one of the most departed ecological response unit at both the plan and context scales. Seral state distribution is severely departed in both the Tonto Basin and Upper Salt zones. Fire suppression, historic grazing, and logging have resulted in a lack of open canopy, lack of large tree dominated stands, larger patch sizes, less groundcover, increased coarse woody debris, and fewer large snags greater than 18 inches in diameter at breast height. Current conditions on the Tonto show a large proportion of this ecological response unit has shifted to the medium/large closed states (61 percent), with a smaller proportion now in the small closed state (21 percent). The context scale shows a similar shift away from the multiple-aged, open structures toward the medium/large closed states, with 63 percent of the acreage currently in this closed condition. Only 11 percent of this ecological response unit on the planning scale is currently in the large, open, multi-storied state indicative of the reference conditions. Much of what remains are even-aged, relatively young stands that did not exist in the reference condition. The combination of unmanaged livestock grazing and fire suppression has drastically reduced the ability of fire to thin dense regrowth (Romme et al. 2009: p. 80).

Fuel continuity has increased in Ponderosa Pine Forest, as open spaces fill in horizontally and vertically, resulting in higher burn severities from wildfire. Twenty-one percent of the Ponderosa Pine Forest on the Tonto has burned with mixed severity, while 16 percent has burned with high severity. Current mean fire return interval is now 84 years as compared to 4 to 30 years in reference conditions. Forests often follow uncharacteristic trajectories after stand-replacing fire, transitioning to dense ponderosa pine that is vulnerable to another fire or to non-forested grass/shrub vegetation states (Savage and Mast 2005).

Future Trend

Vegetation Dynamics Development Tool modeling predicts a small decrease in the proportion of the small, closed, even-aged state and the medium, closed, even-aged states over the next 100 years under current management. The closed canopy, multi-storied, medium/large states are predicted to decrease to 50 percent with a shift from the medium to the larger size class. The medium/large open, multi-storied states are predicted to increase slightly from the current 11 percent to 21 percent.

Models indicate that current management is beginning to move this ecological response unit toward the reference condition; however, predictions also indicate that after 100 years, 73 percent will remain in a closed-canopy state (seedlings/saplings, small closed, medium/large closed). With closed canopies comes increased patch sizes and reduced grass and forb production. Dense stands lead to increased tree mortality and increased accumulation of coarse woody debris. The combination of dense, closed-canopy stands with large patch sizes and high accumulations of coarse woody debris increases the threat of uncharacteristic wildfire. These uncharacteristic wildfires have the potential to significantly alter stand structure or result in type conversion to grass, shrub, or other uncharacteristic systems. Historically frequent, low-severity fires maintained and regulated structure and composition of this ecological response unit (Reynolds et al. 2013).

Ponderosa Pine Forest (PPF)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A, N	Grass/Forb/Shrub	0	2	----	----	0	1	----	1	2
C	Small (open)	0	4	----	----	2	6	----	4	4
D, J, E, K	Medium/Large (open, multi-storied)	100	14	----	----	7	14	----	11	21
B, F	Seedlings/Saplings	0	2	----	----	1	2	----	2	9
G	Small (closed)	0	15	----	----	16	24	----	21	14
H, L, I, M	Medium/Large (closed)	0	63	----	----	74	54	----	61	50
		Departure[3]:	95 (H)	----	----	97 (H)	94 (H)	----	95 (H)	91 (H)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See “Seral State Proportion” section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See “Seral State Proportion” section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size = 0.2 to 0.5 acres. Current patch size = 363 acres. Departure = high.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Native buckwheat (*Eriogonum spp.*) has decreased in abundance, while shrubby deervetch (*Lotus rigidus*) has increased in abundance.

Graminoids: Blue grama and hairy grama grasses (*Bouteloua gracilis* and *Bouteloua curtipendula*) have increased in abundance.

Shrubs and trees: Overall, pointleaf manzanita (*Arcostaphylos pungens*), alligator juniper (*Juniperus deppeana*), Emory oak (*Quercus emoryi*), and desert ceanothus have increased in abundance, while Wright’s silktassel (*Garrya wrightii*) has decreased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Moderate (35%)	Moderate (65%)	Moderate (41%)	High (90%)	**Moderate (62)**
Species present/potential Species	1/3	3/9	1/1	5/5	

1. Forbs include all herbaceous flowering plants.
2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 119 percent

Current = 71 percent

Departure = Moderate (37)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See "Vegetative Groundcover" section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 9.0 tons per acre. Snags greater than 8 inches = 1.1. Snags greater than 18 inches = 0.8

Current: Coarse woody debris = 44.5 tons per acre. Snags greater than 8 inches = 7.8. Snags greater than 18 inches = 0.8

Ecosystem Drivers and Stressors

Fire reference conditions: The fire regime for this ecological response unit is defined as having non-lethal (mostly surface fires) to mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I).

Fire current conditions: Fire return interval = 84 years

Fire severity: Non-lethal: 63 percent. Mixed: 21 percent. Stand-replacing: 16 percent

Fire regime condition class: Class I = 0 percent. Class II = 49 percent. Class III = 51 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed, including an unprecedented, severe outbreak of bark beetles in the 2000s. The recovering areas are at risk for future effects that are not yet quantified.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- Moderate: yellow starthistle (*Centaurea solstitialis*)
- Low: bull thistle (*Cirsium vulgare*), jointed goatgrass (*Aegilops cylindrical*), Scotch thistle (*Onopordum acanthium*)

Twenty-eight acres of noxious weeds have been mapped in this ecological response unit.

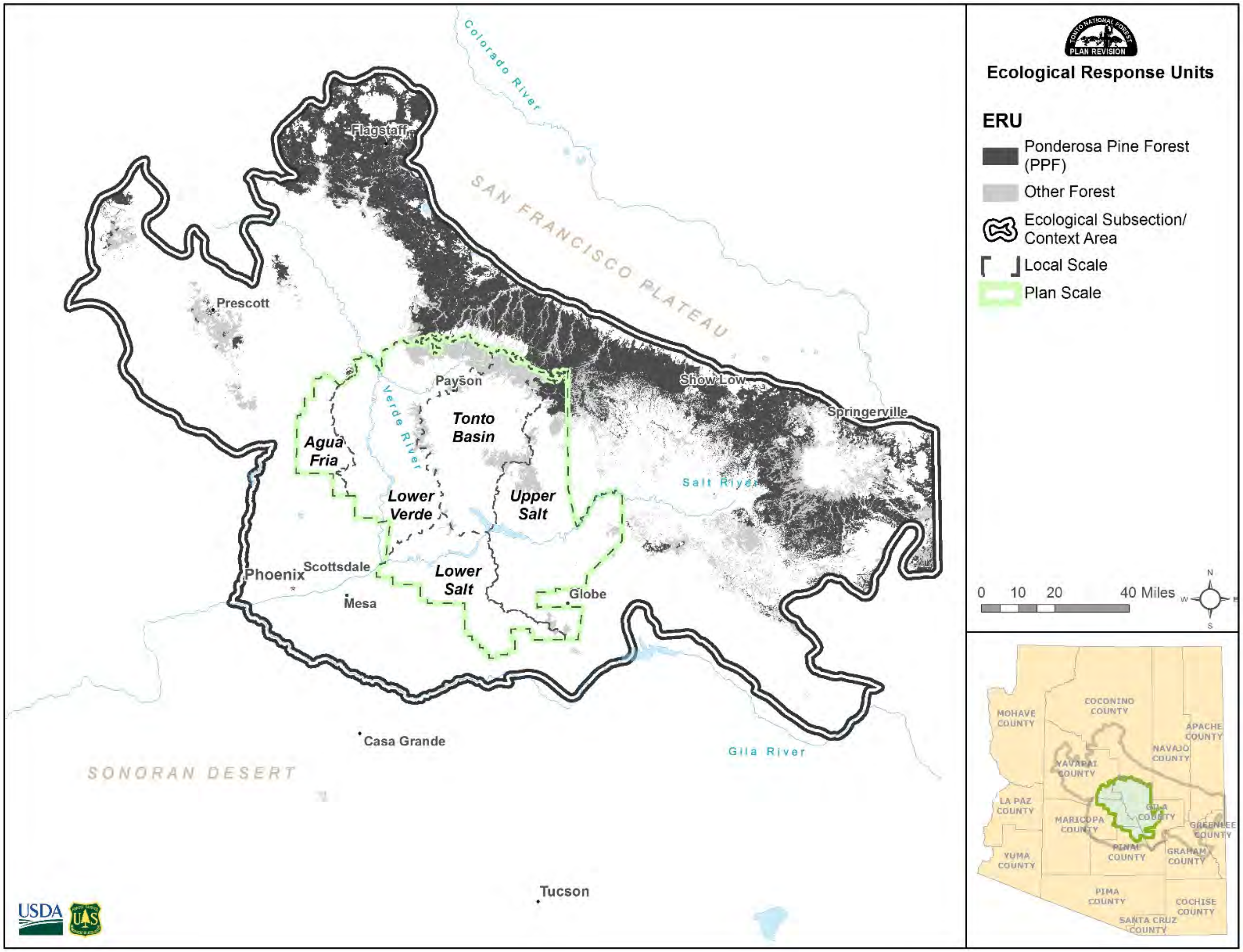


Figure 19. Ponderosa Pine Forest ecological response unit

Mixed Conifer - Frequent Fire (MCD)

Elevation: 6,100 – 10,000 feet

Table 39. Distribution (acres and percent) at the context, plan, and local scales for Mixed Conifer - Frequent Fire

Context	Tonto NF	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
423,765	58,829		24,090	32,101	2,639	
3%	2%		3.1%	5.2%	0.3%	

The terrestrial ecosystem spatial niche analysis assesses the Tonto National Forest's opportunity to influence the context landscape. The Tonto National Forest contribution to the context is the percent of the ecological response unit at the landscape level that intersects the plan area (forest). Proportional representation can range from negative one (low; more common at the context scale) to positive one (high; more common at the plan scale). See the "Terrestrial Ecosystem Spatial Niche" section for complete analysis.

Table 40. Terrestrial ecosystem niche, Mixed Conifer - Frequent Fire

Tonto National Forest Contribution to Context	Proportional Representation	Tonto NF Influence on Sustainability at the Landscape Level (Context Scale)
13.9%	-0.24	Low

Photo 12. Mixed Conifer - Frequent Fire

Also sometimes referred to as Dry Mixed Conifer, the Mixed Conifer - Frequent Fire ecological response unit spans a variety of semi-mesic environments in the Rocky Mountain and Madrean Provinces. In the southwestern United States, mixed conifer forests may be found at elevations between 6,000 and 10,000 feet, situated between ponderosa pine, pine-oak, or pinyon-juniper woodlands below and spruce-fir forests above. This ecological response unit typically occupies the warmer and drier sites of the mixed conifer life zone. Typically these types were dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum*) in an open forest structure (less than 30 percent tree cover), with minor occurrence of aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and southwestern white pine (*Pinus strobiformis*). Aspen can occur within dissimilar inclusions and not as a seral stage in the Mixed Conifer - Frequent Fire ecological response unit. More shade tolerant conifers, such as Douglas-fir, white fir, and blue spruce (*Picea pungens*), tend to increase in cover in late succession, contrary to conditions under the characteristic fire regime. These species could have achieved dominance in localized settings where aspect, soils, and other factors limited the spread of surface fire.

The Mixed Conifer - Frequent Fire ecological response unit covers 58,829 acres on the Tonto and 423,765 acres in the surrounding context area. Representation (distribution) of this ecological response unit on the Tonto National Forest (3 percent) is similar to the context area (3 percent). On the Tonto, this ecological response unit is typically located at higher elevations along the rim, in canyons and on northern aspects where there is sufficient moisture and cooler conditions. At the local scale, most acres are located in the Tonto Basin zone and Lower Verde zone, with lesser amounts in the Upper Salt zone.

Reference Conditions

Fires generally burned as surface fires across these landscapes. In dry years, fires occasionally crowned in areas of concentrated fuels and those with vertically continuous fuels, such as at higher elevations and in mesic, dense sites on north and east aspects. The limiting factor for surface fire was generally moisture, not fuel (Allen et al. 1995; Swetnam and Baisan 1996; Touchan et al. 1996; Fulé et al. 2009; Margolis and Balmat 2009). Historical crown fires in Mixed Conifer - Frequent Fire, were rare (Romme et al. 2009b) and can usually be identified by post-fire cohorts of early-successional trees, such as even-aged stands of quaking aspen. Typical Mixed Conifer - Frequent Fire stands were open with the majority of trees (60 percent) in the medium diameter size class (10 to 19.9 inches) and only 5 percent of this vegetation type in a late seral, closed canopy with large diameter trees (greater than 20 inches) state.

The more common historical mean fire intervals of high-frequency surface fires are similar to that of Ponderosa Pine Forest and likely resulted from the spread of fires from low to higher elevation and the proximity of the two forest types (Allen et al. 1995). Frequent surface fires every 5 to 21 years from low-severity surface fire and infrequent mixed-severity fire (Baisan and Swetnam 1990; Touchan et al. 1995; Heinlein et al. 2005) kept forest structure open, thinning cohorts of tree seedlings and saplings but increasing growth of survivors. Frequent fires kept fuel loads relatively constant spatially and temporally (Touchan et al. 1996; Morgan et al. 2001; Margolis and Balmat 2009) and encouraged understory herb cover. The frequent return of fire in these systems would limit the accumulation of coarse woody debris to levels around 15 tons per acre. Different lengths of fire-free intervals affected tree regeneration. Low-severity, frequent fires favor ponderosa pine and Douglas-fir species, as they develop fire resistant bark at a relatively young age and have other adaptations (for example, self-pruning) to this type of fire regime.

Current Conditions

It is widely accepted that, throughout the southwestern U.S., fire exclusion and past management activities including selective logging and intensive grazing in frequent fire mixed conifer forests have contributed to higher stand densities and altered species composition from mature, large ponderosa pine and Douglas-fir trees shifting toward more shade-tolerant, less fire-resistant species (Moore et al. 2004; Romme et al. 2009) such as white fir and Douglas-fir (Reynolds et al.

2013). Without fire, shade-tolerant, less fire-resistant species are able to establish and mature more easily. White fir and Douglas-fir have in-filled and become more common as dominant species, increasing stand density and species homogeneity (Reynolds et al. 2013). Patch size increased as large overstory trees were harvested and mixed-severity fires no longer maintained heterogeneity (Reynolds et al. 2013).

The current condition on the Tonto demonstrate this shift away from the medium/large open states toward the more closed states. Thirteen percent of this ecological response unit has moved into a medium/large, open canopy, single-storied or two-storied condition that was not common in the reference condition. Medium/large and small closed states have also increased relative to reference conditions. The medium/large closed state has increased from 5 percent to 22 percent, and small closed state has also increased from 5 percent to 22 percent. The proportions in the medium/large, open-canopy, multi-storied state has decreased to only 4 percent from the 60 percent found in the reference conditions. The Tonto Basin zone show the largest departure with a departure rating of high (75 percent) with 48 percent of the seral state proportion in this zone in a medium/large, closed canopy state. The Lower Verde and Upper Salt zones are moderately departed with departure ratings of 54 percent and 42 percent, respectively. The Lower Verde and Upper Salt show less of a shift toward the closed states and more of a shift to the small and early developmental states due to the occurrence of larger uncharacteristic fires in these zones. Most notable are the 1990 Dude, 2002 Packrat, 2004 Webber, 2006 February and 2009 Rim fires in the Lower Verde zone and the Rodeo Chediski of 2002 in the Upper Salt zone. All these fires burned with mixed to stand-replacing intensity in the Mixed Conifer - Frequent Fire vegetation type along the face of the Mogollon Rim.

Both fire exclusion, resulting in current homogenous stands, and past management activities led to increases in patch size averaging nearly 59 acres at the plan scale. Large increases in the number of smaller diameter (less than8 inches in diameter at breast height) snags, an increase in coarse woody debris, and a decrease in ground cover are also likely a result of these conditions as the number of snags, amount of coarse woody debris, amount of ground cover and fire severity are all very interrelated. These changes have also probably increased the potential for bark beetle activity above what would have been expected in pre-settlement conditions and contribute to greater tree mortality when outbreaks do develop.

Future Trend

Vegetation Dynamics Development Tool modeling at the planning scale predicts the shift to the closed canopy states to continue. Early development states, mainly the closed canopy seedling/sapling state F, are predicted to increase to 31 percent by year 100. The medium to large closed states are predicted to increase to 41 percent. With little fire, the medium to large open states, which would have made up 60 percent of the reference landscape, never surpass 7 percent. All open states together never make up more than 14 percent, and trees stay younger than reference on average.

Continued lack of frequent, low-intensity fire allows horizontal and vertical infill by understory trees, especially fire sensitive, shade-tolerant species that were historically suppressed. As the canopies close and densities increase, patch sizes will continue to increase and the amount of grass and forb production continues decreases. The number of snags and the amounts of coarse woody debris will also continue to increases to levels well above historical levels as between tree competition increases mortality rates. These more contiguous, dense stands are unlikely to persist as modeled since it raises the risk of widespread mortality from fire, insects, and disease.

Mixed Conifer - Frequent Fire (MCD)

Overstory Structure and Composition

Seral State Proportion

			Current and Projected Conditions on the Tonto NF[1]							
State	**Description**	**Reference**	**Context Scale**	**1: Agua Fria**	**2: Lower Verde**	**3: Tonto Basin**	**4: Upper Salt**	**5: Lower Salt**	**Plan Scale**	**Projection[2] (100 years)**
A, B, F, N	Early development, all structures	20	9	----	23	8	27	----	15	31
G	Small, closed	5	11	----	12	30	9	----	22	14
C	Small, open	10	5	----	19	6	13	----	12	1
J, K	Medium/Large, open	60	3	----	6	1	18	----	4	7
H, I, L, M	Medium/Large, closed	5	11	----	21	48	7	----	22	41
D, E	Historically rare, Medium /Large, open 1-2 storied canopy	0	9	----	19	7	25	----	13	6
		Departure[3]:	73 (H)	----	54 (M)	75 (H)	42 (M)	----	62 (M)	62 (M)

1. Dashed lines indicate ecological response unit is not sufficiently distributed at scale for analysis.
2. Seral state proportions and departure tend to level off at 100 years (analyzed at the plan scale). See "Seral State Proportion" section for more information.
3. Departure: L = low, (0 to 33 percent); M = moderate, (34 to 66 percent); and H = high, (67 to 100 percent). See "Seral State Proportion" section for explanation on departure calculation.

Average Patch Size (acres at plan scale): Reference patch size: 0.2 to 50 acres. Current patch size = 59 acres. Departure = low, slightly larger.

Understory Structure and Composition

Percent Similarity to Site Potential by Lifeform at Plan Scale

Forbs: Common yarrow and mullein (*Achillea millefolium* and *Verbascum thapsus*) have decreased in abundance.

Graminoids: Muttongrass and long-tongue muhly (*Poa fendleriana* and *Muhlenbergia longiligula*) have increased in some areas.

Shrubs and trees: Fendler's ceanothus (*Ceanothus fendleri*) has increased in abundance, while ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) have decreased in abundance.

Lifeform	Forbs[1]	Graminoids[2]	Shrubs	Trees	All lifeforms (overall)
Similarity to site potential (plan scale)	Low (33%)	Low (24%)	Moderate (34%)	High (76%)	**Moderate (37)**
Species present/potential Species	2/3	1/3	3/3	7/7	

1. Forbs include all herbaceous flowering plants. 2. Graminoids include all grasses, sedges, and rushes.

Vegetative Groundcover (plan scale)

Reference = 132 percent

Current = 68 percent

Departure = High (80)

Plant basal area and litter estimates are combined resulting in single averages that can exceed 100 percent. Departure is based on a nominal ranking system (0 to 33 percent, low; 34 to 66 percent, moderate; 67 to 100 percent, high) and area-weighted by ecological response unit. See “Vegetative Groundcover” section (page 29) for further information.

Key Habitat and Forest Health Components

Coarse Woody Debris and Snags

Reference: Coarse woody debris = 15.2 tons per acre. Snags greater than 8 inches = 9.0. Snags greater than 18 inches = 4.0

Current: Coarse woody debris = 44.8 tons per acre. Snags greater than 8 inches = 19.5. Snags greater than 18 inches = 3.9

Ecosystem Drivers and Stressors

Fire reference conditions: This ecological response unit typically had non-lethal (mostly surface fires) to mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 0 to 35 years (fire regime I). However some areas did experience mixed-severity fires where less than 75 percent of the dominant overstory vegetation is replaced with fire frequencies or return intervals of 35 to 100+ years (fire regime III).

Fire current conditions: Fire return interval = 115 years

Fire severity: Non-lethal = 50 percent. Mixed: 26 percent. Stand replacing = 24 percent

Fire regime condition class: Class I = 23 percent. Class II = 29 percent. Class III = 48 percent

Insect and disease: This system is highly susceptible to effects of insects and pathogens when stressed, including introduction of exotic pathogens. Shifts in community structure due to management practices and climate change could imply increasing risk for other forms of insect and pathogen activities.

Invasive plant species risk status (Arizona Wildlands Invasive Plant Working Group) to ecosystems

- Moderate: yellow starthistle (*Centaurea solstitialis*)
- Low: bull thistle (*Cirsium vulgare*), jointed goatgrass (*Aegilops cylindrical*), Scotch thistle (*Onopordum acanthium*)

No acres of noxious weeds have been mapped in this ecological response unit.

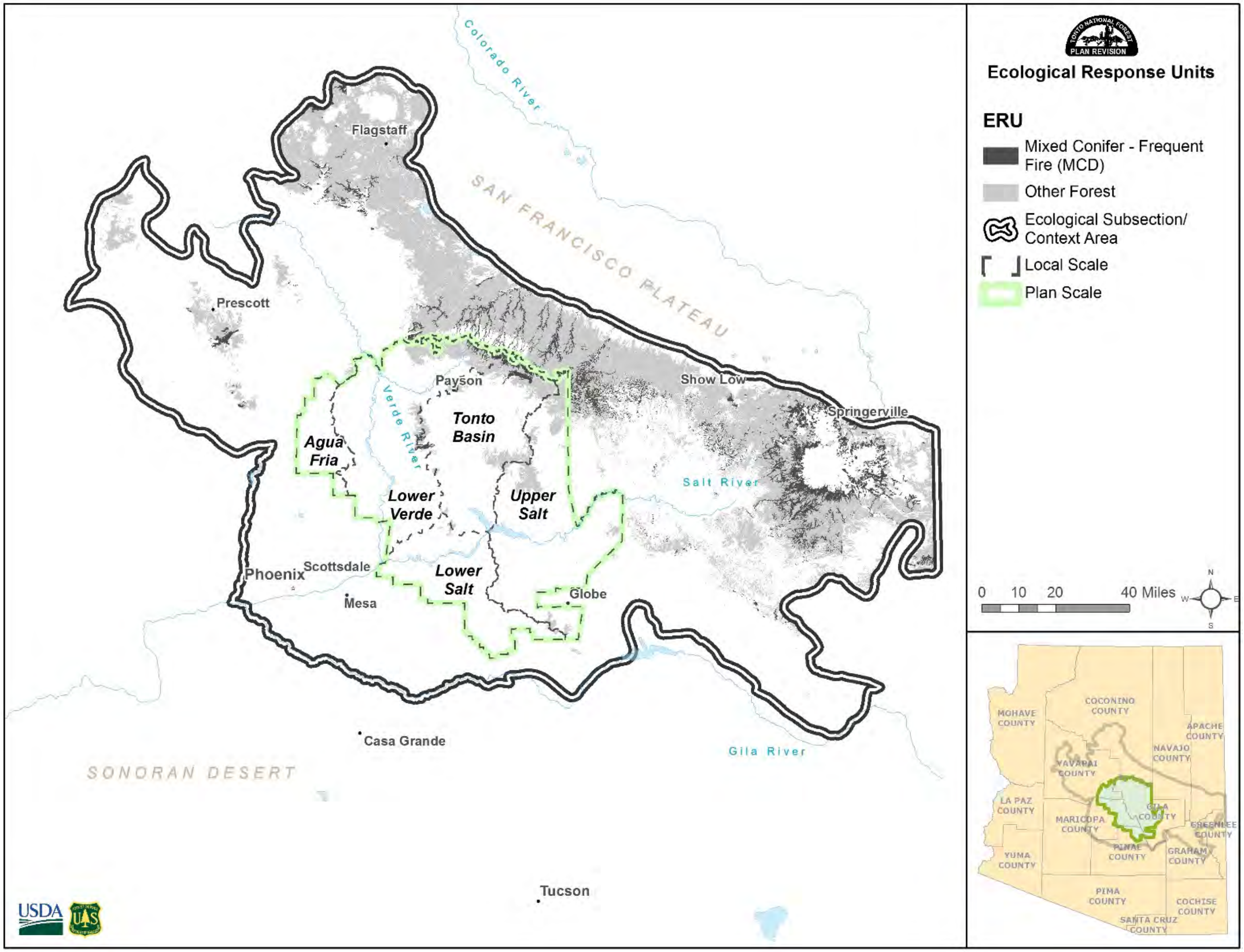


Figure 20. Mixed Conifer - Frequent Fire ecological response unit

Summary of Conditions, Trends, and Risks

The exclusion of wildfire is probably one of the biggest alterations to Southwest landscapes. The removal of wildfire from these ecosystem has led to the degradation, both direct and indirectly, of many of the key ecosystem characteristics. Eighty percent of the vegetation types on the Tonto National Forest evolved with fire as an important ecological process.

Fifty-one percent of the vegetation types experienced fire frequencies of 0 to 35 years: Semi-Desert Grassland, Juniper Grass, Madrean Encinal Woodland, Pinyon-Juniper Grass, Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, and Mixed Conifer - Frequent Fire. Twenty-nine percent of the vegetation types experienced fire frequencies of 35 to 100 or more years: Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Woodland, and Interior Chaparral. The desert communities (Sonora-Mohave Mixed Salt Desert Scrub and Mohave Sonoran Desert Scrub) make up the remaining 20 percent and largely evolved without fire. While the desert communities represent a smaller proportion of all vegetation types, Mohave Sonoran Desert Scrub makes up the single largest (17 percent) community type on the Tonto National Forest and is more common on the national forest compared to the broader landscape (context).

Risk to ecological integrity is highest at mid-elevation fire dependent ecological response units, which is evident by the moderate to high departure for most ecosystem charactersitcs for these ecological response units (table 41). While coarse woody debris and snags are well distributed and abundant for wildlife, these ecological response units have excess amounts beyond reference conditions which can increase wildfire risk and soil loss. The suppression and exclusion of fires and historic harvesting practices (even-aged management) have been major drivers of change that have contributed to altered vegetation structure, highly stressed systems, and degraded ecological integrity, especially among ecological response units that historically supported frequent fires (Ponderosa Pine Forest, Ponderosa Pine - Evergreen Oak, and Mixed Conifer - Frequent Fire). Stressed conditions lower resilience to diseases and pathogens, reduce species diversity, and affect wildlife habitat and use (for example, available wildlife habitat for edge and interior species). These ecological response units have larger patch sizes, high tree densities, and homogeneity of shrub structural stages, all of which set the stage for uncharacteristic wildfire. Fuel loadings (coarse woody debris and tree density) have increased on the national forest and regionally during the 20th century in woodland and forested systems as a result of fire suppression and exclusion. This has led to a higher risk of high burn severity and resulting accelerated erosion, increased loss of soil and less vegetative productivity, and increased sediment transport to connected streams following uncharacteristic wildfires, such as the Rodeo Chediski Fire of 2002. Several woodlands (Interior Chaparral and Juniper Grass) have severe erosion hazard ratings where the potential risk of accelerated soil erosion and risk to ecological integrity is higher following catastrophic fires.

Risk to ecological integrity is high among desert and grassland ecosystems from historical unsustainable grazing, suburban development, and fire exclusion and introduction (in desert communities). The results have been lowered vegetative groundcover, accelerated erosion, soil compaction, and declined soil productivity (see the “Soils” section). This is evident by the moderate to high departure for key ecosystem characteristics; soil condition, soil erosion, fire regime condition class and similarity to site potential (table 41). Forest activities (management actions) have also assisted in the removal of soil surface cover, compaction, and increases in erosion. Activities include road construction and use, prescribed burning, and grazing. Poorly placed roads or roads constructed with poor drainage have also contributed to increased erosion and unsatisfactory soil conditions. Fire exclusion has indirectly affected rangelands as woody species are encroaching, succession is becoming stagnant, with limited acreage moving back into an early successional state, and reduced nutrient cycling is occurring.

The introduction of fire and exotics in desert communities has had the largest influence on current and projected departure. Under natural disturbance regimes, fire occasionally occurred; however, fuel loads were discontinuous patches that greatly limited the spread of fires. Today, the presence of exotics and uncharacteristic shrub densities have resulted in contiguous fuel sources that increase the risk of wildfire and loss of native species. Where vegetation is sparse and potential for exotic invasion is lower, repeated disturbance has reduced soil condition and shifted dominance of long-lived species to disturbance-adapted species. Fungi and soil crusts play key roles in ecological functioning and significantly reduce erosion potential from wind and water. Repeated disturbance can significantly reduce or eliminate biological crusts that can negatively affect seedling germination, plant growth, and nutrient availability – especially among sparse community types in arid environments. The impaired soils in these ecological response units may indicate a loss in biological soil crusts that further increase the risk of ecological intgerity of these ecosystems.

Historically, semi-desert grasslands were some of the most diverse and highly productive community types. Risk to ecological integrity of Semi-desert grasslands are due to a loss of fire, overgrazing by livestock, removal of keystone species (prairie dogs), and exotic grass establishment and spread. This has resulted in shrub encroachment, erosion, and habitat fragmentation and type conversion throughout a significant proportion of semi-desert grasslands regionally. Loss of soils in these community types have strong influences on vegetation structure and species composition. Without frequent fires, changes in the surface soils over time result in the dominance of deep-rooted shrubs and trees and the elimination of shallow-rooted grasses. Today, many sites resemble a disclimax state where soil-binding, perennial grasses have been replaced by shrubs and annuals (native and exotic) that compete with grasses. Some sites have been altered to a point where site conditions are too departed to restore to open perennial grasslands. While the Tonto National Forest only represents 20 percent of the semi-desert ecological response unit at the context scale, the opportunity for ecosystem maintenance and restoration is high given the increasing loss of grasslands regionally. Additionally, a moderate amount of acres have high potential for restoration and other assessments have identified a significant proportion of restorable acres of semi-desert grasslands on the Tonto National Forest.

Considering current long-term drought (roughly since about 2000), reduced precipitation results in reduced vegetative growth, reduced surface organic matter and nutrient cycling, and lower site productivity. Ineffective vegetative groundcover puts the soil at risk of accelerated erosion during peak storm events, with subsequent erosion and loss of soil productivity. Limited water availability and increased competition from overstocked stands increases competition and stress resulting in potential vegetation mortality. Reduced fuel moistures and predisposed vegetation is at increased risk of wildfire and insect and disease infestations and subsequent accelerated erosion and overall watershed degradation.

General effects from climate change to ecosystems are discussed here. Refer to the “Climate Change” section for a complete discussion of climate change vulnerability by major ecological response units on the Tonto National Forest. Results from recent climate models are not encouraging. Multiple models are in agreement that the southwestern United States is in a drying trend that will continue well into the latter part of the 21st century (Intergovernmental Panel on Climate Change 2007; Seager et al. 2007). Models also agree that conditions and trend will continue to depart from reference conditions. Increased precipitation is predicted; however, temperatures are also expected to increase. The balance between precipitation and evaporation would likely result in an overall decrease in available moisture. This ultimately results in fewer precipitation events and more precipitation in a shorter period, with larger, more destructive flooding. Herbaceous cover is likely to die-off in prolonged drought and leave larger areas devoid of groundcover, creating an increased amount of bare soil. Storms may become more intense.

More intense storms, coupled with a lack of groundcover, will increase erosion resulting in unsatisfactory soil conditions. Increased temperatures also threaten surface water with increased evaporation as well as an increased demand for groundwater.

Table 41. Summary of risk to terrestrial ecological integrity

Ecological response unit	Seral state proportion	Similarity to site potential	vegetative ground cover	Coarse woody debris	Snag density	Patch size	Fire regime	FRCC	Insect & disease	Soil Condition	Soil Erosion Hazard
Mixed Conifer - Frequent Fire (MCD)	M	M	H	L	L	L	H	M	H	L	H
Ponderosa Pine Forest (PPF)	H	M	M	L	L	H	H	M	H	L	H
Ponderosa Pine - Evergreen Oak (PPE)	M	H	L	L	L	H	M	M	H	L	H
Madrean Encinal Woodland (MEW)	M	M	M	L	L	L	H	M	L	L	H
Pinyon-Juniper Woodland (PJO)	L	H	M	L	L	M	H	M	H	M	H
Pinyon-Juniper Evergreen Shrub (PJC)	H	H	M	L	L	L	M	M	H	H	H
Juniper Grass (JUG)	M	H	M	L	L	H	H	M	L	M	H
Pinyon-Juniper Grassland (PJG)	M	H	M	L	L	H	H	M	H	H	L
Interior Chaparral (IC)	L	H	L	L	L	M	H	M	L	L	H
Semi-Desert Grassland (SDG)	H	H	M	L	L	H	M	M	L	M	H
Mohave Sonoran Desert Scrub (MSDS)	L	H	L	L	L	L	L	H	L	M	H
Sonora-Mojave Mixed Salt Desert Scrub (SDS)	L	H	M	L	L	L	M	M	L	H	H

Departure is based on a nominal classification; H (High greater than 66 percent), M (Moderate 33 to 66 percent) and L (Low less than 33 percent). Data is not available for blank cells.

Chapter 4. Soils

Introduction

Soil provides many benefits on which other life forms (including humans) depend by providing a substrate and nutrients for plants, through thermoregulation (daytime heat absorption, nighttime heat release), nutrient cycling, and water purification and storage. Soils provides wildlife habitat (burrows, dens), plant-growth media (nurseries), and fill (construction).

The diverse and productive soils of the Tonto are described, characterized, and classified in the draft terrestrial ecological unit inventory of the Tonto National Forest (Robertson et al. 2014). The information regarding the kind of soils on the Tonto is intricately linked to the climate, vegetation, and geology of the Tonto.

Geology

The Tonto National Forest occurs in a geologically diverse area that spans three distinct ecological sections. For purposes of this report, the Tonto National Forest will be summarized by each of these ecological sections due to similarity in geomorphology and lithology. The three sections to be summarized are the Sonoran Desert, Tonto Transition, and White Mountain-San Francisco Peak-Mogollon Rim (Fenneman 1916).

- The Sonoran Desert section of the Tonto National Forest is in the Basin and Range physiographic province and the American Semi-Desert and Desert province. This section is located in southwestern Arizona and makes up the southern and lower elevations of the Tonto National Forest. The Range portions of this physiographic section are dominated by structural bedrock, and common landscapes are mountains and hills. The lithology of these areas are dominated by volcanic andesitic and rhyolitic tuff ranging from 11 to 38 million years in age, granitic rock ranging from 1400 to 1800 million years in age and to a lesser extent metasedimentary rock ranging from 1600 to 1800 million years in age. The Basin portions of this physiographic section are dominated by fluvial geomorphic processes producing basins, fan piedmonts, and plain landscapes. The lithology of the basin portions of this section are dominated by surficial deposits ranging in age from 0 to 750 thousand years in age from single or multiple sources.
- The Tonto Transition section of the Tonto National Forest is located between the Basin and Range and Colorado Plateau physiographic provinces and is part of the Colorado Plateau Semi-Desert province. The Tonto Transition section makes up a majority of the Tonto National Forest, meeting the Sonoran Desert section to the south and the White Mountain-San Francisco Peak-Mogollon Rim section to the north. Precambrian through Mesozoic Volcanic activity and sedimentary deposition are major geomorphic processes in this section. Common landscapes in the Tonto Transition section include Fan Piedmonts, Foothills, Hills, and Mountains. The lithology of the Tonto Transition is complex and, in places, highly dissected. Dominant lithology includes granitic rock ranging from 1400 to 1450 million years in age, sedimentary rock ranging from 770 to 1300 million years in age, diabase ranging from 1050 to 1150 million years in age, basaltic rock ranging from 8 to 16 million years in age, and alluvial deposits ranging from 2 to 16 million years in age.
- The White Mountain-San Francisco Peak-Mogollon Rim section of the Tonto National Forest is in the Colorado Plateau physiographic province and the Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Conifer Forest-Alpine Meadow province. The White Mountain-San Francisco Peak-Mogollon Rim section of the Tonto National Forest makes up

the smallest portion of the Tonto and is located in the northwest part. This portion of the White Mountain-San Francisco Peak-Mogollon Rim section located on the Tonto National Forest is a plateau landscape dominated by a sequenced lithology of sedimentary rocks 330 to 540 million years in age, 280 to 310 million years in age, and 270 million years in age.

Climate

The climate is highly variable as a consequence of the uneven topography, wide range in elevation and seasonal distribution of precipitation. The elevation ranges from a low of 1,300 feet near Granite Reef Dam on the southwestern end of the Mesa Ranger District to a high of 7,900 feet at Mazatzal Peak located in the central area of the Tonto National Forest on the Cave Creek Ranger District. Climate varies from the hot, dry Sonoran Desert at the lower elevations to the cool, moist montane coniferous forest at the higher elevations.

Plant communities follow a climatic, elevational gradient from low elevation Sonoran desert scrub, to semi-desert grasslands, to pinyon-juniper woodland, to mid elevation ponderosa pine forest, and to mixed conifer forest. The majority of the Tonto National Forest Sonoran desert scrub, semi-desert grasslands, evergreen oak, pinyon-juniper woodlands, and ponderosa pine forest plant communities are in the mild winter climatic zone. Ponderosa pine and mixed conifer plant communities on the upper portions of the Sierra Anchas Mountains and the Pinal Mountains, and those located within the White Mountain-San Francisco Peak-Mogollon Rim ecological section are in the cold winter climatic zone.

Soils

Across the Tonto National Forest, soils vary from an aridic (dry) moisture regime and a hyperthermic (extremely hot) temperature regime at the lower elevations in the Sonoran Desert scrub vegetation to an udic (humid-subhumid) moisture regime and a frigid (cold winter, warm summer) temperature regime in the mixed conifer forests at the highest elevations.[2]

On steeper slopes, soils tend to be shallow and skeletal (containing more than 35 percent rock fragments) due to naturally higher rates of erosion and a slower rate of soil development. There is less soil development on the more unstable steeper slopes. Moderately steep to flat slopes tend to have deeper, more developed soils, and rock fragment content can be variable. Soil texture varies by parent material kind and origin. Soils developed in parent material such as diabase and basalt tend to have a higher clay content because these parent materials are high in minerals that more easily weather into clay sized particles. Soils formed from granite, metasedimentary and tuff parent materials are lower in clay content because these parent materials are high in minerals that are resistant to weathering into clay-sized particles.

Soil diversity on the Tonto National Forest is characterized by using Soil Taxonomy (1999). Soil properties are described and grouped into taxonomic classes according to Soil Taxonomy, and this grouping allows for differentiating soils based upon their inherent characteristics along with important functions such as soil productivity. Soils on the Tonto are grouped into soil orders. Of the ten global soils orders, five are mapped on the Tonto National Forest: Alfisols, Aridisols, Entisols, Inceptisols, and Mollisols.

[2] For a complete explanation of soil temperature and moisture regimes, see *Keys to Soil Taxonomy, 12th ed.* (Soil Survey Staff 2014).

Ecosystem Characteristics for Assessment

Soil erosion hazard and soil condition are directly linked to the ability of the soil to withstand disturbances from management activities and natural events, while maintaining site productivity and sustainability of the soil resource. These characteristics are used to analyze the reference and current conditions and future trends of the soil resource. The soil erosion hazard rating reflects inherent site and soil characteristics. Soil condition rates soils as they exist currently and reflects the effects of management and disturbance history. Soils were generally assumed to be in satisfactory soil condition under reference conditions.

Soil Erosion Hazard

Soil erosion hazard is the probability of soil loss resulting from complete removal of vegetation and litter. Slope, soil texture, and vegetation type greatly influence soil erosion hazard rating. It is an interpretation based on the relationship between the maximum soil loss and the tolerable (threshold) soil loss of a site. Soils are given a slight, moderate, or severe erosion hazard rating.

- A rating of **slight** indicates the maximum soil loss does not exceed the threshold; therefore, the loss of the soil production potential is of low probability.
- A **moderate** erosion hazard indicates that the loss in soil production potential from erosion is probable and significant if unchecked.
- A **severe** erosion hazard rating indicates that the loss of soil production potential from erosion is inevitable and irreversible if unchecked.

These ratings provide land managers an index for identifying three classes of land stability. They are useful in determining where erosion control measures should be evaluated when (or before) the soil surface has been exposed by vegetation management activities (for example, fuel wood cutting, timber harvest, thinning, mastication, etc.), grazing, prescribed burning, mining, or other disturbances. These ratings are also useful in identifying areas that should receive minimum exposure of mineral soil and in determining areas with the greatest potential for response to seeding after wildfire. Severe ratings mean that accelerated erosion is likely to occur in most years and that erosion control measures should be evaluated.

Soil Condition

Soil condition is an evaluation of soil quality based on an interpretation of factors which affect vital soil functions. Soil quality is the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin 1994). The interrelated functions of soil hydrology, soil stability, and nutrient cycling are evaluated to assess soil condition.

- **Soil hydrology:** This function is assessed by evaluating or observing changes in surface structure, surface pore space, consistence, bulk density, infiltration, or penetration resistance using appropriate methods. Increases in bulk density or decreases in porosity result in reduced water infiltration, permeability, and plant-available moisture.
- **Soil stability:** Erosion is the detachment, transport, and deposition of soil particles by water, wind, or gravity. Vascular plants, soil biotic crusts, and litter cover are the greatest deterrents to surface soil erosion. Visual evidence of surface erosion may include rills, gullies, pedestalling, soil deposition, erosion pavement, or loss of the “A” (surface) horizon. Erosion models are also used to predict on-site soil loss.

- **Nutrient cycling:** This function is assessed by evaluating plant community composition, litter, coarse woody material, root distribution, and soil biotic crusts. These indicators are directly related to soil organic matter, which is essential in sustaining long-term soil productivity. Soil organic matter provides a carbon and energy source for soil microbes and provides nutrients needed for plant growth. Soil organic matter also provides nutrient storage and capacity for cation and anion exchange.

Soil condition was evaluated using Terrestrial Ecosystem Unit Inventory data for the Tonto National Forest in conjunction with the Technical Guide for Soil Quality Monitoring in the Southwestern Region (2013). A soil condition category rating (described below) was determined for each Terrestrial Ecosystem Unit Inventory map unit based on the three soil functions listed above; the Terrestrial Ecosystem Unit Inventory soil condition classes were aggregated for the respective ecological response unit (USDA Forest Service 2013; Wahlberg et al. 2013).

Soil Condition Categories

Ecological response units are assigned a soil condition category which is an indication of the status of soil functions. Soil condition categories reflect soil disturbances resulting from both planned and unplanned events. Current management activities provide opportunities to maintain or improve soil functions that are critical in sustaining soil productivity. The following is a brief description of each soil condition category:

- **Satisfactory:** Indicators signify that soil function is being sustained, and soil is functioning properly and normally. The ability of soil to maintain resource values and sustain outputs is high.
- **Impaired:** Indicators signify a reduction of soil function. The ability of soil to function properly has been reduced or there exists an increased vulnerability to degradation. An impaired rating should signal to land managers a need to further investigate the ecosystem to determine causes and degrees of decline in soil functions. Changes in management practices or other preventative actions may be appropriate.
- **Unsatisfactory:** Indicators signify that loss of soil function has occurred. Degradation of vital soil functions results in the inability of soil to maintain resource values, sustain outputs, and recover from impacts. Soils with an unsatisfactory rating are candidates for improved management practices or restoration designed to recover soil functions.
- **Unsuited:** Areas rated unsuited are those where geologic erosion rates are greater than soil formation rates. Soils are inherently unstable and may occur on steep slopes. These soils are generally associated with badlands and other miscellaneous areas.

Unlike soil erosion hazard, soil condition is influenced by management. Existing management activities need to be evaluated to determine if the current management activity is contributing to the loss of soil function. In some cases, current management activities may not have caused the loss of soil function but may be preventing recovery. Management activities that slow or prevent recovery of soil function should be avoided.

Satisfactory soil condition (soil quality) is important in maintaining long-term soil productivity, which is key to sustaining ecological diversity. Unsatisfactory and impaired soil conditions have resulted in the reduced ability of the soil to grow plants and sustain productive, diverse vegetation.

Associated Stressors

Stressors and disturbance agents that influence erosion hazard and soil condition and are likely to affect future demand and availability have been considered in this assessment.

- **Erosion/mass wasting** is manifested as rill or gully erosion, pedestalling, soil and litter deposition on the uphill side of rocks and vegetation, and erosion pavements. High levels of erosion lead to increased soil loss and decreased soil productivity (USDA Forest Service 1991; IPCC 2007).
- **Loss of effective vegetative groundcover** is indicated by a lack of surface roots, perennial forbs and grass, and litter. Vegetation loss may result in a higher risk of wind and water erosion, particularly on steeper slopes where erosion hazard is already high.
- **Uncontrolled mechanical impacts** such as compaction, displacement, and mastication, lead to weak, massive, or platy soil structure; a reduction in tubular surface pore space; and a hard non-biotic surface crust, contributing to impaired and unsatisfactory soil conditions.
- **Climate change** modelers predict an increase in air temperature and a possible drying trend that will continue into the latter part of the 21st century (IPCC 2007; Seager et al. 2007). Despite predictions for increased precipitation, modelers believe the balance between precipitation and evaporation would still likely result in an overall decrease in available moisture. While the region is expected to dry out, it is likely to see larger, more destructive flooding. Herbaceous cover is likely to die off in prolonged drought and leave larger areas devoid of groundcover, creating an increased amount of bare soil. More intense storms, coupled with a lack of groundcover, will increase wind and water erosion, resulting in unsatisfactory soil conditions.
- **Burning:** Prescribed burns and wildfires decrease effective overstory canopy and vegetative groundcover. Due to climate change, forest ecosystems could face increased fire hazards in the future (IPCC 2007; Seager et al. 2007).
- **Herbivory,** including high levels of cattle, elk, and other ungulate grazing, has been observed to reduce effective vegetative groundcover and contribute to accelerated soil erosion, soil compaction (Carleton et al. 1991), and declined soil productivity (especially during periods of drought). It has been observed that unmanaged grazing results in sparse herbaceous vegetation and high amounts of bare soil, resulting in unsatisfactory soil conditions (Carleton et al. 1991).

Reference Condition, Current Condition, and Trend

Erosion Hazard

Erosion hazard is a function of vegetation, landform, and slope. Because slope and landform are not dynamic properties in human lifetime scales, the current trend is similar to the reference condition. However, a large vegetation removal event such as wildfire could cause this trend to change. Given the increase in probability of uncharacteristic wildfires, as well as climate change, sustainability of soils in terms of erosion hazard is unknown. The effects of severe erosion create a greater risk to downslope and downstream resource values. Because slope, vegetation, and fire potential are similar between the national forest and the broader landscape, conditions and trends will also be similar between that of the Tonto National Forest and its surroundings.

Erosion hazard was determined based on percent slope for this assessment. The severe erosion hazard class includes ecological response units occurring on steep landforms with a slope of greater than 40 percent (mountain slopes, escarpments, hills), primarily Interior Chaparral, Juniper Grass, Mixed Conifer- Frequent Fire, Pinyon-Juniper Woodland and Ponderosa Pine Forest (figure 21). Where these systems occur in watersheds with excessive fuel loadings and uncharacteristic disturbance regimes, the potential risk for accelerated soil erosion exceeding thresholds and subsequent runoff is high.

Sites that predominantly have moderate erosion hazard on moderately sloping (15 to 40 percent) landforms support the Pinyon-Juniper Evergreen Shrub, Ponderosa Pine - Evergreen Oak, Semi-Desert Grassland, and Sonoran-Mojave Mixed Salt Desert Scrub ecological response units.

The majority of sites with predominantly slight erosion hazard ratings occur on moderately sloping to nearly level landforms (0 to 15 percent slope) including piedmont plains, alluvial fans, valley plains, stream terraces, and floodplains and support the Pinyon-Juniper Grass, Sonoran-Mojave Creosote-Bursage Desert Scrub and all Riparian ecological response units. Although these ecological response units have low erosion hazard potentials, soil loss from lack of vegetative groundcover contributes to unsatisfactory and impaired soil conditions.

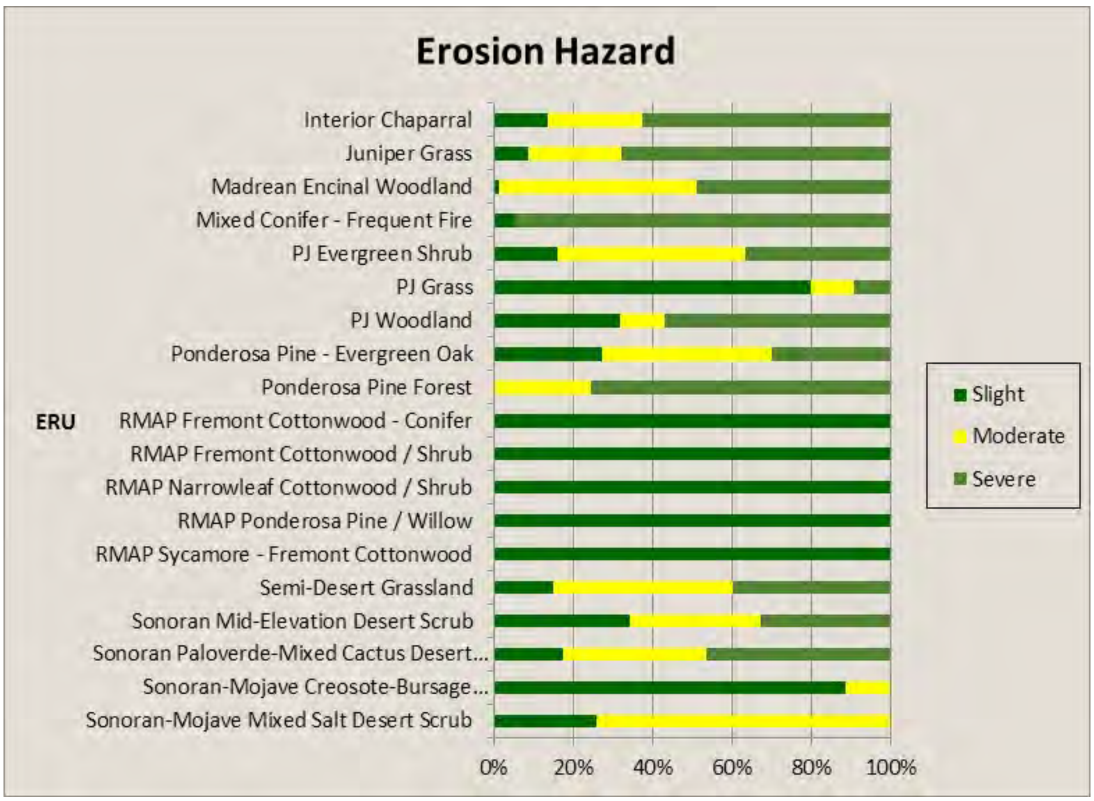


Figure 21. Erosion hazard on the Tonto National Forest for the major upland and riparian ecological response units

Soil Condition

Very little quantitative data exist to measure historical soil condition. However, some qualitative and quantitative inferences can be made, providing insight into historical soil condition by using knowledge about present disturbances and their effect on soil stability, soil compaction, and nutrient cycling. Reference conditions generally estimate pre-European settlement conditions.

Historically (without anthropogenic disturbance), soil loss, soil compaction, and nutrient cycling would probably have been within functional limits to sustain soil function and maintain soil productivity for most soils that are not inherently unstable, the exception being during cyclic periods of drought and possibly local areas impacted through non-domestic herbivory. Natural flood disturbance would have had a limited effect on the extent of soil loss, only causing accelerated erosion adjacent to stream channels or floodplains. Drought may have reduced the amount of protective vegetative groundcover resulting in accelerated erosion during prolonged rainstorms. Most areas that are currently impaired and unsatisfactory for soil condition would probably have been historically satisfactory for soil condition.

Table 42. Estimated historic versus current soil condition percentages on the Tonto National Forest

Soil Condition Class	Historical Percent	Current Percent	Difference between Historical and Current
Satisfactory	88%	35%	53%
Impaired	Low	32%	32%
Unsatisfactory	Low	16%	16%
Unsuited	16%	16%	0%

The most productive soils (satisfactory soil condition) historically and currently are within the Interior Chaparral, Mixed Conifer-Frequent Fire, Ponderosa Pine-Evergreen Oak, Ponderosa Pine Forest, Fremont Cottonwood-Conifer, and Ponderosa Pine/Willow ecological response units (figure 22). These ecological response units produce high amounts of biomass and organic matter to maintain soil cover to ensure stability of the soil and support nutrient cycling.

Other ecological response units that historically were very productive and assumed to have satisfactory soil condition but are now impaired through a reduction in soil function include the Narrowleaf Cottonwood/Shrub and the Sonoran Paloverde- Mixed Cactus Desert Scrub ecological response units. The lack of effective vegetative groundcover and organic matter has resulted in unstable soils with reduced hydrologic function and nutrient cycling in these ecological response units.

The Pinyon-Juniper Grass, Fremont Cottonwood/Shrub, Sycamore-Fremont Cottonwood and Sonoran-Mojave Creosote-Bursage Desert Scrub ecological response units are all at least 40 percent unsatisfactory (figure 22). In these ecological response units, lack of vegetative groundcover (observed mainly as insufficient litter, basal area, and subsurface roots) may be contributing to decreased hydrologic function and stability.

Additionally, some soils are considered unsuited-inherently unstable. Unsuited-inherently unstable soils are those in which their geologic formation and geomorphic properties (for example, steep slopes) are naturally active, and soil erosion has existed historically and will continue. Unsuited-inherently unstable soils are dispersed across the landscape and occur primarily in the Juniper Grass and Madrean Encinal Woodland ecological response units. Soil erosion hazard influences soil condition; an inherently unstable soil is more vulnerable to soil condition impairment than an inherently stable soil.

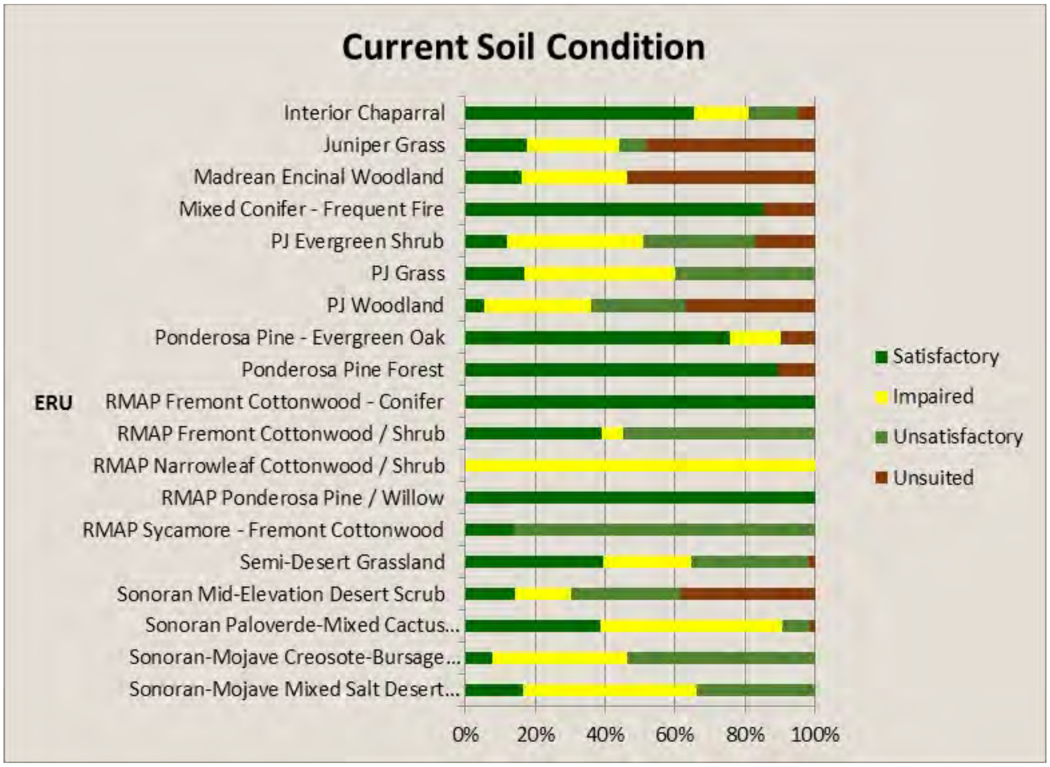


Figure 22. Current soil condition on the Tonto National Forest for the major upland and riparian ecological response units

To account for soils that are unsuited-inherently unstable, soil condition should be at least 50 percent satisfactory to match historic, or reference, condition. However, the data show at least 50 percent impaired and unsatisfactory soils in over half (53 percent) the ecological response units, indicating a need for change in current management, particularly in the Pinyon-Juniper, Sonoran Desert, and the majority of the Riparian ecological response units.

Until unmanaged herbivory is reconciled and the frequency and magnitude of disturbances occur within the historic range of variation (Schussman and Smith 2006), the trend will continue to move away from reference condition, at the same, or at an increased, rate. This will affect soil productivity, which will in turn affect forage production and other resources on the Tonto National Forest. As with erosion hazard, soil condition trends are similar on both private and public lands. However, on adjacent National Forest System lands, soil condition is improving to satisfactory due to changes in management. On the Coconino National Forest, for example, current soil condition is 79 percent satisfactory with only 10 percent unsatisfactory, and slightly over 10 percent unsuited-inherently unstable (Coconino 2007). With a change in current management, some factors of soil condition, like overstory canopy and groundcover, may improve quickly. Other factors take a long time to improve (recovery of lost topsoil) and could impact resources for quite some time.

Risk Assessment

Risk was calculated based on percent departure from reference condition (figure 23). Reference condition includes the slight erosion hazard and satisfactory soil condition categories; all other categories (except unsuited soil condition) are considered departure from reference condition.

High risk is determined as greater than 67 percent departure, moderate risk is 34 to 66 percent departure and low/no risk is 0 to 33 percent departure.

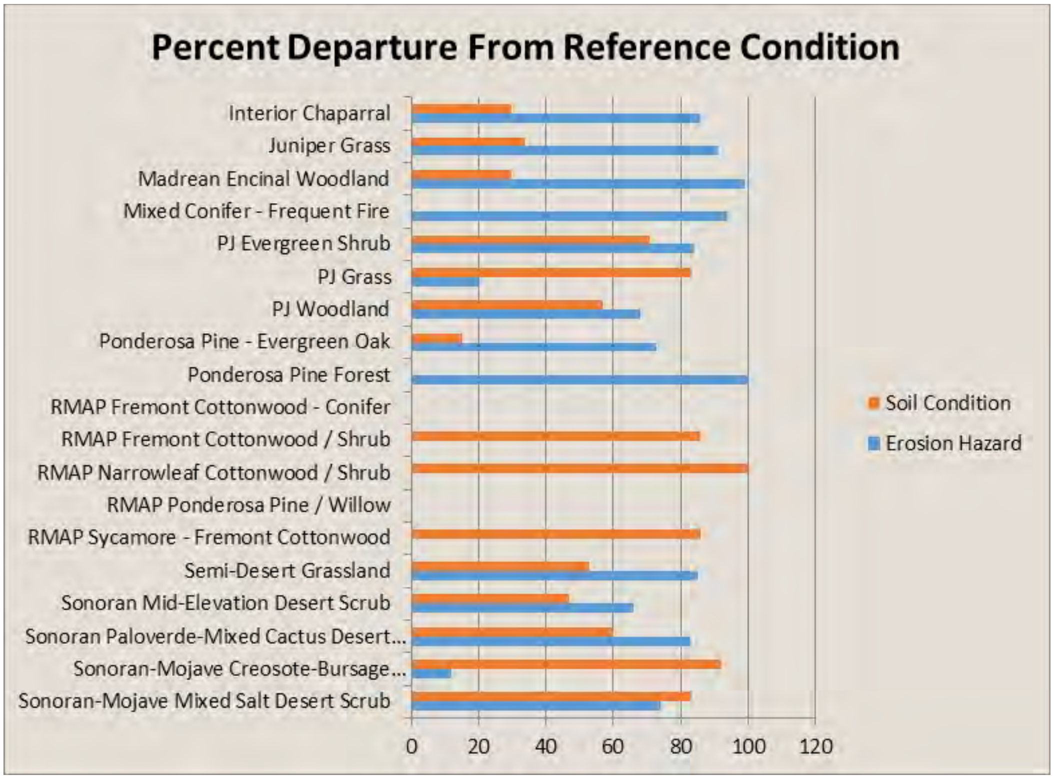


Figure 23. Percent departure from reference condition, erosion hazard and soil condition, for all the major upland and riparian ecological response units on the Tonto National Forest

Erosion hazard: Over half of the Tonto ecological response units (58 percent) are at high risk for erosion. Only one ecological response unit, the Sonoran Mid-Elevation Desert Scrub, is at moderate risk for erosion. The remaining 37 percent of ecological response units are at low/no risk for erosion. Riparian units make up 71 percent of the low or no risk category.

Soil condition: Risk for soil condition is more evenly dispersed between ecological response units, with 37 percent at high risk, 26 percent at moderate risk and 37 percent low or no risk.

Local scale units: Ecological response units are aggregated up into five local scale units by hydrologic unit code 8 watersheds: Aqua Fria, Lower Salt, Lower Verde, Tonto, and Upper Salt. Because each ecological response unit typically makes up only a small percentage of each local unit, with some ecological response units not occurring at all in several of the local units, risk may be inaccurately identified as low when looking at the broader local scale. However, the Sonoran Paloverde-Mixed Cactus Desert Scrub ecological response unit, which makes up 58 percent of the Lower Salt local unit, stands out as being at moderate risk for both soil condition and erosion within that particular unit. This may be one area to focus particular attention when creating the forest plan. Ecological need for change should address the site-specific characteristics (plant basal cover, canopy cover, litter, coarse and fine woody material, etc.) in need of improvement.

Chapter 5. Riparian Ecosystems

A riparian area is the interface between the terrestrial and aquatic ecosystem. As ecotones, they encompass sharp gradients of environmental factors, ecological processes, and plant communities (Gregory et al. 1991). Riparian areas are plant communities contiguous, to and affected by, surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian ecosystems are defined as transition areas between the aquatic ecosystem and the adjacent terrestrial ecosystem; they are identified by soil characteristics or distinctive vegetation communities that require free or unbound water (USDA Forest Service 2013). Although riparian areas make up a small percent of the context landscape (table 43), they support some of the greatest plant and animal diversity and are essential habitat for much of the native flora and fauna and migratory avian species.

Riparian areas are defined by change and are adapted to disturbance. Because of variability in the amount, timing, distribution, and duration of water availability in the Southwest, shifts in runoff, erosion, sedimentation, vegetation resistance to disturbance and resilience are site specific and episodic. Properly functioning riparian systems reach a “dynamic equilibrium” where, on the whole, sediment movement is sustainable and hydrologic forces of change are balanced by deposition and vegetation recovery (DeBano et al. 1995).

In Arizona and New Mexico, an estimated 80 percent of all vertebrate species use riparian areas for at least half their life cycles, and more than half of these are totally dependent on riparian areas (Chaney et al. 1990). Likewise, aquatic and fish productivity are directly related to a properly functioning and healthy riparian habitat. These areas are typically characterized by key riparian plant communities that have significant influences on the ecological integrity of riparian ecosystems. They experience routine inundation by water during seasonal high flows and storm events.

Structure of Riparian Assessment

First, the assessment of key ecosystem characteristics for each riparian ecosystem type (riparian ecological response units) on the Tonto National Forest are presented. Second, the risk to the ecological integrity of riparian ecosystems is assessed and lastly summary and key findings are presented. The scales of analysis for riparian ecosystems follow the same spatial extents defined for terrestrial ecosystems (reference chapter 3, Spatial Scales of Analysis).

Riparian Ecological Response Units

The riparian mapping project (RMAP) was a collaborative effort between the Southwestern Region of the Forest Service and other organizations to map and describe riparian systems or ecological response units in the region, Arizona and New Mexico (Triepke et al. 2014a). Specific reference conditions have not been developed for riparian ecological response units, but maintaining or restoring riparian function that support equilibrium will, in turn, promote ecological integrity. One objective of the riparian mapping project was to provide planning teams with spatial data on riparian features sufficient to complete ecological sustainability analyses and planning at landscape scales (1:24,000 scale and greater). The riparian ecological response units have the most extensive covering of the Tonto National Forest for riparian areas, as well as the context area surrounding it. The riparian mapping project does not include the entire context area, nevertheless it covers more area than any other inventory the Tonto National Forest has in its possession. Some riparian ecological response units were grouped based on similar dominant vegetation species. The following riparian ecological response units were analyzed:

- Cottonwood Group ecological response unit
    - Narrowlead Cottonwood/Shrub
    - Sycamore-Fremont Cottonwood
    - Fremont Cottonwood/Shrub
    - Fremont Cottonwood-Oak
- Fremont Cottonwood-Conifer ecological response unit
- Ponderosa Pine/Willow ecological response unit
- Desert Willow ecological response unit

Other riparian ecological response units on the Tonto, such as the Arizona Alder-Willow, Herbaceous Riparian, and Sparsely Vegetated ecological response units, were not included in the analysis due to insufficient data and few acres on the Tonto. The ecological response units carried forward in this analysis make up 2.9 percent of the Tonto National Forest (table 43).

Table 43. Riparian ecological response unit (RMAP) distribution at local, plan and context scales

Riparian Ecological Response Units (RMAP)	Local Scale/Zone										Plan		Context	
	1 Agua Fria		2 Lower Verde		3 Tonto Basin		4 Upper Salt		5 Lower Salt					
	Number of Acres	% of RMAP acres	% of Local Scale	% of RMAP acres	% of Local Scale	% of RMAP acres	% of Local Scale	% of RMAP acres	% of Local Scale	% of RMAP acres	RMAP Acres	% of RMAP acres	RMAP Acres	% of RMAP acres
Desert Willow	286	12	2,325	9	349	2	3,863	15	2,129	27	8,951	11	41,604	22
Fremont Cottonwood - Conifer	207	9	3,639	14	7,848	35	875	3	130	2	12,699	15	13,293	7
Cottonwood Group	1,825	79	17,211	64	11,896	53	20,547	81	5,584	71	57,063	67	124,568	66
Ponderosa Pine/Willow	*	*	3,686	14	2,234	10	143	1	*	*	6,063	7	7,146	4
Total Riparian ERU Acres	2,318		26,861		22,327		25,427		7,843		84,777		101,835	
Percent of Riparian Acres by Land Area	1.3%		3.2%		3.4%		3.1%		1.7%		2.9%		0.8%	

* No acres are present at this scale

For each riparian map unit, the number of acres are displayed along with the percent of all riparian acres the unit represents at a given scale. Riparian acres and percent by land area/scale are displayed in the last two rows of the table. The scales of analysis for riparian ecosystems follow the same spatial extents defined for terrestrial ecosystems (reference chapter 3, Spatial Scales of Analysis).

Key Riparian Ecosystem Characteristics

The key ecosystem characteristics for riparian vegetation (ecological response units) include

- similarity to site potential,
- vegetative groundcover,
- upland condition (wildfire risk), and
- riparian condition.

Ecological Status or Similarity to site potential measures the degree of similarity between existing and natural (reference condition) plant communities for each riparian ecological response unit. The natural plant community (reference conditions) is a suite of species expected to occupy a site based on edaphic (soil properties) and climatic properties under natural disturbance regimes. Existing and natural communities are developed from the terrestrial ecological unit inventory, ecological classifications built from extensive field data on vegetation, climate, and soils (Jenny 1958, USDA Forest Service 1986b). Some riparian ecological response units contain several or more terrestrial ecological unit inventory map units. Similarity to site potential is calculated by species for each riparian ecological unit inventory map unit, using the similarity to site potential equation (USDA Forest Service 1997) and area weighted by riparian ecological response unit to represent weighted similarity at the plan scale. The same process was repeated by species within each lifeform category (forb, shrub, graminoid, and tree) to display community level patterns that may be unequally influencing the overall site similarity or departure from similarity. The terrestrial ecological unit inventory plot data is not sufficient in resolution to analyze ecological status by local scale.

Riparian species composition and community structure is largely influenced by moisture regimes, flood disturbance patterns (timing, magnitude, and frequency), and other landscape features (substrate, soils, and geology). Because riparian species tend to have very narrow or specific moisture regimes, the presence or absence of certain species can indicate changes in local site conditions. For example, drying conditions may be evident by the under-representation of wetland-obligate (only found at wetlands) species and increases in facultative-upland or upland species (mostly occur at uplands). A number of riparian species are groundwater dependent (generally requiring shallow groundwater levels), so dominance by upland plants at the riparian zone may indicate a declining water table (USDI BLM et al. 1998). The loss of these native riparian species can also have large influences on ecosystem function and integrity. Riparian species, such as willow (*Salix* spp.), Arizona alder (*Alnus oblongifolia*), and Fremont cottonwood (*Populus fremontii*) prefer wetter conditions and have root masses capable of withstanding high-flow events (USDI BLM et al. 1998). Native aquatic species like sedges and rushes colonize scoured areas soon after floods, capture sediment, and keep stream substrates from eroding. Native riparian graminoids (grasses and grass like plants) have extensive root masses that are strong and fibrous and stabilize streambanks, and resist undercutting during high flow events. Sod-forming annual grasses, which have shallower and more delicate root systems, are less resistant to erosion. Erosion leads to bank undercutting and collapse and changes the active channel’s width-to-depth ratio, gradient, and sinuosity, which reduces a riparian area’s ability to dissipate energy.

Groundcover is an important characteristic that moderates overland flow and streamflow by regulating flow rate and encouraging infiltration down into the soil profile. Disruption of the surface cover and alteration of the mineral soil by wildfire can produce changes in the hydrology of a watershed well beyond the range of historic variability (DeBano et al. 1998). Riparian vegetation can directly affect stream channel characteristics, particularly streambank habitat and stability (Abernethy and Rutherfurd 2001). Root systems protect stream banks through armoring (Abernethy and Rutherfurd 2001) and bind bank sediment, thus contributing to bank stabilization, reduction of sediment inputs to streams (DeBano et al. 1998), and development and maintenance of undercut banks. There are marked differences among riparian species and vegetation types in root characteristics and their influence on bank stability (Wynn et al. 2004). Management activities, such as logging and grazing, and natural disturbances, such as fire and debris flows, can directly affect stream bank stability through alteration of riparian vegetation.

Upland condition is the condition of the surrounding uplands. Upland condition can substantially affect the condition of a riparian area. Despite riparian systems not being fire adapted, fire is an important disturbance in western riparian systems as the effects of fire, when within its historical range of frequency and severity in upland systems, result in beneficial effects in riparian systems. Higher soil moistures, cooler temperatures, and greater productivity typically characterize riparian areas. In general, this means under wetter conditions, fire intensities should be lower in riparian areas and result in patchy, mosaic-type burns. The lack of fire creates less patchiness, lower diversity of plants and structure, and fewer associated animals. Increased conifer and overall vegetation density and uniformity in the riparian area result in higher-intensity fires across large areas. Fire also aids in the maintenance of coarse woody debris, which creates pools that provide habitat for fish and other aquatic organisms. Fires can either result in more accumulation of wood or even a complete removal of wood from the vicinity of the stream depending on preexisting forest and fire severity. However, continuous fuels can also aid the movement of fire from adjacent uplands into the riparian areas. When uncharacteristic high-severity fire sweeps through an adjacent landscape adapted to low-intensity surface fire (for example, Mixed Conifer – Frequent Fire), the effects on riparian areas can be dramatic. High-severity fire resulting in the loss of riparian vegetation can lead to higher water temperatures, increased erosion, reduced oxygen concentrations, and reduction in the distribution of aquatic biota through the reduction in the amount of vegetation providing stream shading or cover.

Fire also effects overland flow, when the vegetation that typically intercepts rainfall and encourages infiltration is burned up. High-severity wildfire can consume all, or nearly all, the protective vegetative cover and litter layer over extensive watershed areas, producing a significant effect on the magnitude of overland flow and sedimentation (DeBano et al. 1998) that negatively affects aquatic organisms (Neary et al. 2005). This is especially significant in the southwestern U.S. where monsoonal precipitation following high-severity fire has increased peak flow rates hundreds of times greater than pre-fire rates (Ffolliott and Neary 2003). In some cases, it may take decades for the stream and associated riparian corridor to recover. Changes in upland condition can change the discharge, timing, or duration of streamflow events and the amount of sediment supplied to a riparian area. Uplands that are able to store less water or that are more erodible or more prone to uncharacteristic fire will have a negative effect on adjacent riparian systems; however, degraded upland conditions does not always result in degraded riparian conditions.

Upland condition was evaluated from the top two to three dominant adjacent vegetative communities and ecological response units by area within ¼-mile buffer of each riparian map unit. Seral state departure (current and 100-year projection) and current fire regime condition class values for adjacent ecological response units were area weighted to derive upland condition score and departures. Detailed analysis and assessment of the adjacent ecological response units is described in the “Terrestrial Ecosystems” section of this assessment.

Riparian Condition (Tonto Stream Assessment) is the only key ecosystem characteristic unique to riparian areas and not in the upland vegetation ecological response unit section. It is a methodology for assessing the physical functioning of riparian-wetland areas. The Tonto stream assessment method was developed on the Tonto National Forest in 1996 and was revised in 1998 and 2001. Stream reaches that were assessed, classified, or both were chosen by project level work. Many were chosen because they are considered key reaches, and accessibility by people and animals was a factor. Key riparian reaches, similar to upland key areas, are those stream channels, springs, and riparian areas selected to indicate achievement of management objectives. Key riparian reaches were sampled because they are representative, responsive to changes in management, contain key riparian species, and are accessible to livestock. It was reasoned that improved management for the key reaches would increase the likelihood of protection or recovery for all streams in the area. Therefore, the assessments and classifications may not be representative of the riparian areas in the watershed as a whole but rather representative of our more key areas. Some reaches were visited more than once, in which case the most recent data was used.

The riparian condition analysis is based on stream channel stability which is defined as the ability of a stream to carry the water and sediment of its watershed while maintaining its dimension, pattern, and profile, without aggrading or degrading over time and in the present climate (Rosgen 1996). Parameters used to assess stability include depositional pattern, stream bank vegetative cover (Thompson et al. 1998), stream channel width-to-depth ratio, channel stability rating (Pfankuch 1975), and bank erosion hazard index (Rosgen 1996). The condition rating classes are stable, impaired (slightly or severely), or unstable. All impaired ratings (slightly impaired and severely impaired) were combined for this planning effort. The stream assessment data only covers lands within the Tonto National Forest boundary and therefore cannot be used to evaluate riparian conditions outside the boundary.

Stream assessment data is available on the Tonto National Forest from the last decade, but only the most current data (latest year) for each assessed stream was used for this assessment. Two analysis approaches were taken to describe current trends in ecological integrity throughout the ecological response unit specific analysis section and trends and conclusions section:

1. Riparian condition was assessed for each riparian ecological response unit only at the plan scale. Riparian condition is not assessed for each riparian ecological response unit at any finer scale (local scale) because the resolution of the data is too coarse (that is, there are too few analyzed streams forestwide).
2. To analyze riparian condition by plan and local scales, a different approach was taken where the stream data was intersected with local and plan scale extents in GIS. This analysis describes the overall condition of riparian streams at plan and local scales (not specific to ecological response units).

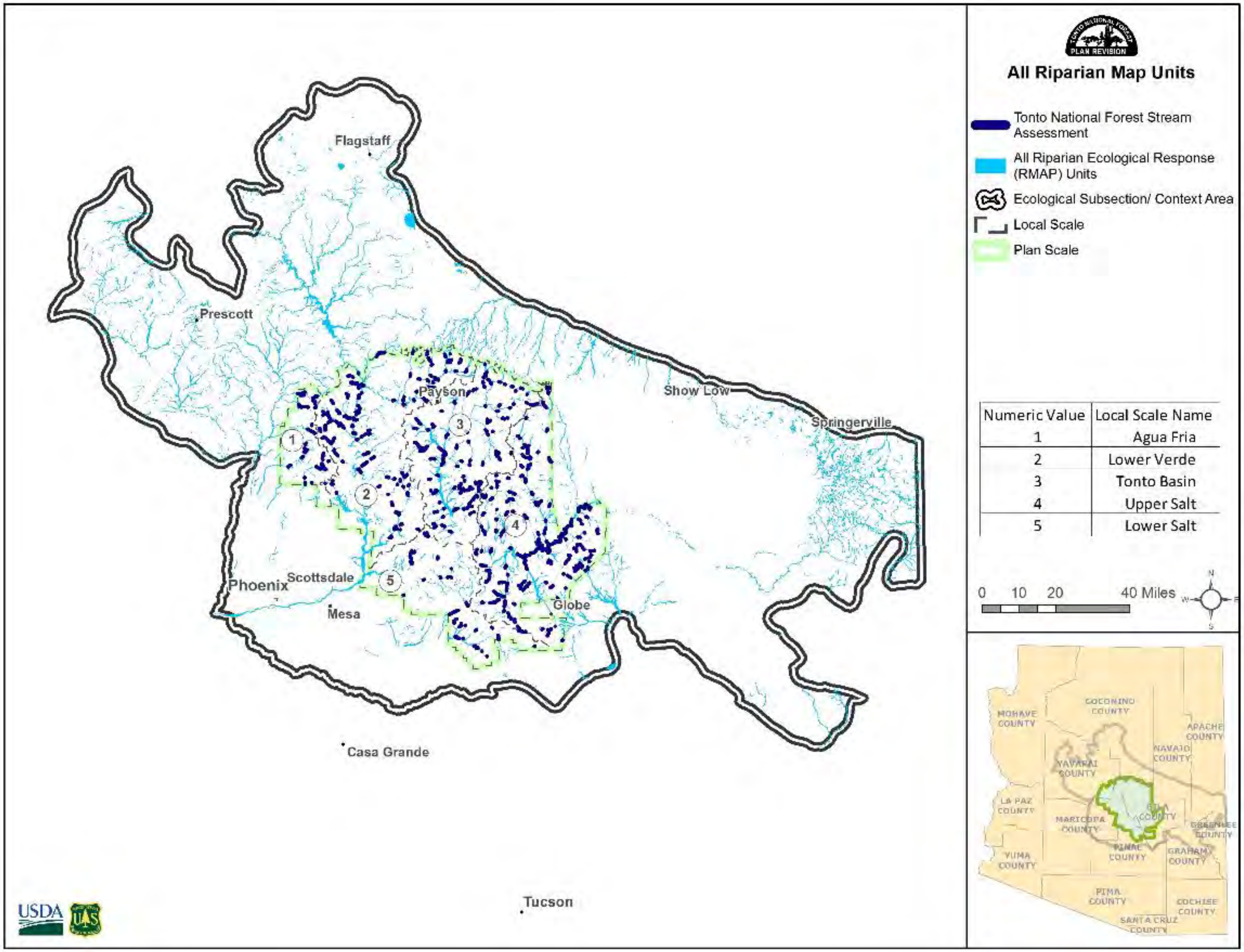


Figure 24. Map showing riparian condition (Tonto stream assessment) available for data analysis, relative to the location of riparian ecological response units

Reference Conditions of Riparian Ecosystems

Similar to terrestrial vegetation, reference conditions will be used to determine the amount of departure and ecological risk to riparian systems. It is assumed that restoring and maintaining riparian function that supports equilibrium will, in turn, promote ecological integrity. Riparian ecosystems are ecological hotspots and serve multiple functions for humans, other vegetation systems, and wildlife. Continuous corridors of riparian vegetation cover hundreds of miles and served as permanent habitat and seasonal migration routes for many species of birds and mammals. Rivers and spring-fed cienegas supported specialized, endemic fish species. Beavers required water and created ponds to retain it during periods of low flow. Other species, like the southwestern willow flycatcher, depend on the plant and animal communities of riparian wetlands. The spatial and temporal distribution of riparian ecosystems across the landscape is dependent on climate, geology, and hydrology, collectively. It is not known what combination of conditions maintained these productive sites. Frequent fires and periodic floods may have contributed to the lack of tree or shrub cover, but the inability of most trees to compete with grasses on deep soils may also have been a factor. It is likely most of these canyons flooded periodically, especially in high precipitation years. Floods are the most important disturbance type in many riparian ecosystems. Floods on riparian vegetation affect a wide range of ecological attributes including vegetative abundance, distribution, structure, function, composition, and site productivity. Unfortunately, historic flood regimes on the Tonto National Forest are unknown. Fire frequency is the only other disturbance regime for which the Tonto has extensive data; therefore, it will be used as a proxy since the diversity of riparian areas can be attributed to the temporal variability in natural disturbances including, debris flows, landslides, and wildfire (Gecy and Wilson 1990, Naiman et al. 2005).

Successional patterns of riparian plant community development are driven by responses to natural and anthropogenic disturbances, physical variables, and plant species attributes (Baker 1989, Merritt et al. 2010). There is also feedback between riparian plant species and the physical environment. These involve plant features that influence sediment deposition and accumulation and lead to stabilization of streambanks and floodplains. Riparian plant characteristics include mechanical resistance and flexibility, root anchorage ability, and post-disturbance regeneration via sprouts and seedlings that influence sediment deposition and accumulation (Pettit and Naiman 2007, Corenblit et al. 2009). Thus, the diverse composition and structure of riparian vegetation are a result of the interdependence of physical and biotic processes over time (Simon et al. 2004).

Wetland and riparian areas have historically been heavily impacted by anthropogenic activities throughout North America (Brinson and Malvárez 2002). Extensive land uses by Native Americans and European-Americans likely had some impact on riparian areas on the Tonto. Wetlands and riparian ecosystems have been subject to a number of stressors including hydrologic alterations associated with dams and water diversions (Graf 1993, Nilsson and Berggren 2000), agricultural drainage (Dahl 1990), grazing (Fleischner 1994, Patten 1998, Belsky et al. 1999), and the widespread introduction of nonnative species (Stein and Flack 1996, Mack et al. 2000). Demand for water, fertile land, and forage for livestock in the arid and semi-arid West has already affected many aquatic, riparian, and wetland areas and pressures will likely increase with time, threatening the integrity and long-term viability of these vital ecosystems and the biota they support (Baron et al. 2002).

Desert Willow

Elevational range on the Tonto: 1,490 – 4,554 feet. **Average elevation:** 2,492 feet

Photo 13. Desert Willow Riparian ecological response unit

The Desert Willow riparian ecological response unit is often found in dry washes, intermittent streams, and often along ephemeral and drier reaches of interrupted alluvial channels. Desert willow (*Chilopsis linearis*) makes up the dominant stratum of this ecological response unit. Other commonly associated tree species include netleaf hackberry (*Celtis reticulata*) and velvet mesquite (*Prosopis velutina*). Shrubs such as burrobush (*Ambrosia* spp.) and desert broom (*Baccharis sarothroides*) are also commonly associated with this ecological response unit. Like other desert trees (such as mesquite, *Prosopis* spp.), desert willows are adapted to drought conditions through their ability to extract groundwater at the phreatic zone of the water table (that is, phreatophytes). Desert willow trees are also long-lived species that aid in bank stabilization of water courses and occasionally contribute to the formation of islands within the riparian channel by trapping sediments following flood events (Uchytil 1990).

Distribution and Representation

The Desert Willow ecological response unit makes up 22 percent of analyzed riparian ecological response unit acreage (2nd largest ecological response unit) at the context scale. This ecological response unit is the 3rd largest, making up 11 percent of all analyzed riparian ecological response units on the Tonto National Forest. It is most abundant at the Lower Salt (27 percent of riparian acres) and Upper Salt (15 percent of riparian acres) local zones. Figure 25 displays the general location of the Desert Willow ecological response unit within the context area and the Tonto National Forest. The opportunity for the Tonto National Forest to contribute to the ecological integrity of this ecological response unit at the broader landscape scale (context area) is low to moderate as 8,951 of the 41,604 acres (22 percent of the context acres) are located on the Tonto (table 44).

Table 44. Distribution of Desert Willow (acres and percent) at context, plan, and local scales

Acres Measured	Context	Tonto National Forest	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Desert Willow Acres	41,604	8,951	286	2,325	349	3,863	2,129
Total RMAP acres*	186,611	84,777	2,318	26,861	22,327	25,427	7,843
Desert Willow Percent of Analyzed RMAP acres*	22%	11%	12%	9%	2%	15%	27%

* These acres only include the riparian mapping project (RMAP) units analyzed in this assessment: Desert Willow, Fremont Cottonwood-Conifer, Cottonwood Group, and Ponderosa Pine/Willow ecological response units.

Key Riparian Ecosystem Characteristics

Riparian Condition

Over half (59 percent) of the streams assessed for this ecological response unit are unstable, much higher than the 31 percent of unstable streams assessed forestwide. While the analysis of riparian condition by ecological response unit is restricted to the plan area or forest boundary, the Upper Salt zone has the highest proportion of unstable and impaired streams where the Desert Willow ecological response unit is the 2nd most abundant on the Tonto. Additionally, the Lower Salt zone has the highest proportion of Desert Willow ecological response unit acres, and this zone has the highest proportion of unstable streams forestwide.

Table 45. Riparian condition by Desert Willow ecological response unit and streams by local and plan scales

Riparian Condition Class	Riparian Condition (percent) by Riparian ERU (plan scale)	Riparian Condition (percent) for all Analyzed Streams by Plan and Local Scale					
	Desert Willow ERU	Plan Scale	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Unstable	59	31	24	28	37	30	42
Impaired	19	51	25	51	49	62	32
Stable	22	18	51	21	14	8	26

* Riparian condition is analyzed by riparian ecological response unit at the plan scale by intersecting Tonto stream assessment data by riparian ecological response unit. Reference “Tonto Stream Assessment” section in the introduction for more information.

** Riparian condition is assessed for all streams by local scale and not for riparian ecological response unit by local scale because the stream assessment data is not sufficiently distributed across the Tonto to do such analysis.

Ecological Status (Similarity to Site Potential)

There is insufficient terrestrial ecological unit inventory plot data for this riparian ecological response unit to analyze similarity to site potential.

Vegetative Groundcover

There is insufficient terrestrial ecological unit inventory plot data for this riparian ecological response unit to analyze vegetative groundcover.

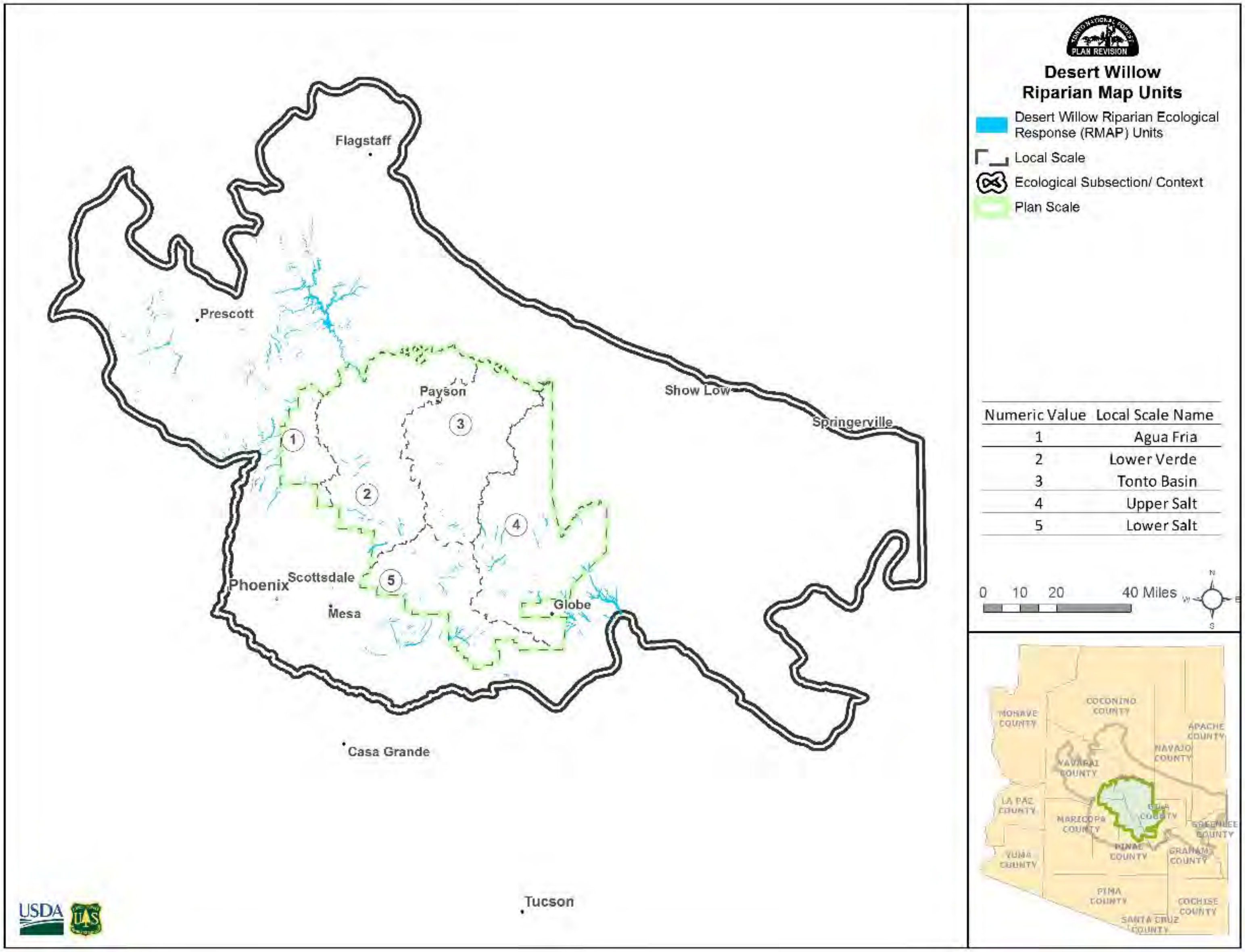


Figure 25. Desert Willow riparian map units

Upland Condition

Uplands with degraded ecological conditions that are more prone to uncharacteristic wildfire can have negative effects on adjacent riparian systems. While degraded upland conditions do not always result in direct impacts to riparian areas, they can indirectly affect the discharge, timing, or duration of streamflow events and the amount of sediment supplied to a riparian area.

For this ecological response unit, the upland condition analysis does not sufficiently capture potential impacts to riparian channel function and condition because most Desert Willow riparian areas are located within sandy washes that are naturally unstable and capable of transporting relatively large volumes of sediment following flood events. Other riparian ecosystem characteristics are more applicable to describing status (discussed below).

Table 46. Upland condition analysis for Desert Willow ecological response unit (ERUs)

Dominate Adjacent upland vegetation or ERUs at Riparian Corridor*	Averaged Current Seral State departure for Adjacent ERUs**	Averaged 100-year Projection of Seral State departure for Adjacent ERUs**	Percent acres by Fire Regime Condition Class for Adjacent ERUs**
Mojave-Sonoran Desert Scrub and Semi-Desert Grassland	Low (31)	High (77)	FRCC I (low departure): 33 percent FRCC II (moderate departure): 14 percent FRCC III (high departure): 54 percent

* Upland condition is evaluated for each riparian ecological response unit by analyzing the top 2 to 3 dominant adjacent vegetation or ecological response units by area within the riparian corridor (¼-mile buffer).

** Seral state departure (current and 100-year projection) values and current fire regime condition class values for adjacent ecological response units are area weighted by riparian corridor to derive upland condition score/departures.

Key Trends

Risk to the ecological integrity of this ecological response unit is high as only 22 percent of assessed streams on the Tonto National Forest Tonto National Forest are rated stable. Risk is also highest at the Lower and Upper Salt zones. These local scales have the highest proportion of Desert Willow acres and the highest proportion of unstable and impaired streams. These riparian areas and the adjacent uplands (desert scrub) experience heavy recreational impacts (off-highway vehicle use). Additionally, the Lower Salt zone borders the Phoenix metropolitan area where a large number of uses recreate. While there is currently no information on soil condition for this ecological response unit, repeated ground disturbance (for example, user-created trails, off-highway vehicle use) can cause impaired soil conditions (compaction), reduced plant vigor, and lower species diversity. Impaired site conditions are present at sites by the significant amount (59 percent forestwide) of streams rated as unstable. Unstable streams have the lowest level of plant diversity and contribute the least towards ecological integrity – potentially contributing to poor water quality and reduced water quantity.

Fremont Cottonwood – Conifer

Elevational range on the Tonto: 2,060 – 5,709 feet. **Average elevation:** 3,279 feet

Photo 14. Fremont Cottonwood-Conifer ecological response unit

The Freemont Cottonwood-Conifer ecological response unit is typically found at elevations ranging from 2,100 to 8,800 feet. Fremont cottonwood (*Populus fremontii*) and conifers, such as Utah juniper (*Juniperus osteosperma*), share the dominant stratum of this ecological response unit. Other plant species include net leaf hackberry (*Celtis reticulata*) and velvet mesquite (*Prosopis velutina*). Fremont cottonwood is a pioneer species and has many characteristics that allow colonization of disturbed areas. It produces a prolific number of small seeds at a young age. It establishes mainly from seed rather than asexually production, although it can sprout shoots from lateral buds on stems prostrated by flood flows (Stromberg, 1993). Flooding is the primary disturbance in cottonwood systems, and germination and establishment of the trees coincide with flood events. Fremont cottonwood and the associated woody species in this ecological response unit are important in erosion control and riparian functionality (for example, stabilizing banks).

Distribution and Representation

The Fremont Cottonwood-Conifer ecological response unit makes up 7 percent of analyzed riparian ecological response unit acreage at the context scale. This ecological response unit is the 2nd largest, making up 15 percent of all analyzed riparian ecological response units on the Tonto National Forest. It is most abundant at the Tonto Basin (35 percent of riparian acres) and Lower Verde (14 percent of riparian acres) local zones. Figure 26 displays the general location of the Fremont Cottonwood-Conifer ecological response unit within the context area and the Tonto National Forest. The opportunity for the Tonto National Forest to contribute to the ecological integrity of this ecological response unit at the broader landscape scale (context area) is high as 12,699 of the 13,293 acres (95 percent of the context acres) are located on the Tonto (table 47).

Table 47. Distribution of Fremont Cottonwood-Conifer (acres and percent) at context, plan, and local scales

Acres Measured	Context	Tonto National Forest	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Fremont Cottonwood - Conifer acres	13,293	12,699	207	3,639	7,848	875	130
Total RMAP acres*	186,611	84,777	2,318	26,861	22,327	25,427	7,843
Fremont Cottonwood-Conifer Percent of Analyzed RMAP acres*	7%	15%	9%	14%	35%	3%	2%

* These acres only include the riparian mapping project (RMAP) units analyzed in this assessment: Desert Willow, Fremont Cottonwood-Conifer, Cottonwood Group, and Ponderosa Pine/Willow ecological response units.

Key Riparian Ecosystem Characteristics

Riparian Condition

With the exception of the Ponderosa Pine/Willow ecological response unit, the Fremont Cottonwood-Conifer ecological response unit has least amount of unstable streams compared to the other riparian ecological response units. It also has a lower number of streams rated unstable (24 percent) compared to the proportion of unstable streams forestwide (31 percent). While the analysis of riparian condition by ecological response unit is restricted to the plan area and forest boundary, the Tonto Basin zone has the 2nd highest proportion of unstable streams where the Fremont Cottonwood-Conifer ecological response unit is the most abundant. Conditions are less impaired at the Lower Verde zone where the Fremont Cottonwood ecological response unit is the 2nd most abundant on the Tonto.

Table 48. Riparian Condition by Fremont Cottonwood-Conifer riparian ecological response unit and streams by local and plan scales

Riparian Condition Class	Riparian Condition (percent) by Riparian ERU (plan scale)	Riparian Condition (percent) for all Analyzed Streams by Plan and Local Scale					
	Fremont Cottonwood-Conifer ERU	Plan Scale	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Unstable	24	31	24	28	37	30	42
Impaired	56	51	25	51	49	62	32
Stable	20	18	51	21	14	8	26

* Riparian condition is analyzed by riparian ecological response unit at the plan scale by intersecting Tonto stream assessment data by riparian ecological response unit. Reference “Tonto Stream Assessment” section in the introduction for more information.

** Riparian condition is assessed for all streams by local scale and not for riparian ecological response unit by local scale because the stream assessment data is not sufficiently distributed across the Tonto to do such analysis.

Ecological Status (Similarity to Site Potential)

Ecological status for the Fremont Cottonwood-Conifer ecological response unit is highly departed from reference conditions as only 6 percent of similarity exists between the potential natural community and the current plant community. Probably the largest influence to the low similarity to site potential is influenced by the low forb abundance. Nonnative forbs, such as filaree (*Erodium cicutarium*), have become naturalized in this ecological response unit (and throughout

North America) and are generally present at low levels. A general shift to drier conditions may be occurring as there is an overabundance of species, such as alligator juniper (*Juniperus deppeana*) and pinyon pine (*Pinus edulis*), that tend to occur at the uplands more than wetlands (facultative upland species). Additionally there is poor representation of species that favor wetlands (facultative wetland and obligate wetland species), such as Fremont cottonwood (*Populus fremontii*) and Arizona sycamore (*Platanus wrightii*). Grasses (sod versus bunch) can have significant influences on site productivity, water infiltration, stream temperature, and sedimentation. Grasses such as black grama (*Bouteloua eriopoda*) are intensive exploiters for limited shallow soil moisture and can survive decades once established (USDA-NRCS 2016). Changes in grass species abundance can indicate a shift in local site conditions (for example, available plant moisture). In general, grass abundance is low for this ecological response unit – specifically native bunch grasses, such as black grama (*Bouteloua eriopoda*) and blue grama (*Bouteloua gracilis*). The overall low abundance of native grass and forb species indicate a loss of site productivity.

Table 49. Fremont Cottonwood-Conifer ecological response unit lifeform and overall similarity to site potential (percent similarity)

Lifeform[1]	Similarity to Site Potential (percent)[2]	Species and Lifeforms Over-represented	Species and Lifeforms Under-represented
Forbs	Low (0%)	None	*Eriogonum spp.* Filaree (*Erodium cicutarium*)
Graminoids	Low (7%)	None	Blue Grama (*Bouteloua gracilis*) Black Grama (*Bouteloua eriopoda*) Hairy Grama (*Bouteloua hirsuta*)
Shrubs	Low (16%)	Wright's silktassel (*Garrya wrightii*) Broom Snakeweed (*Gutierrezia sarothrae*) Red Barberry (*Berberis haematocarpa*)	Sonoran Scrub Oak (*Quercus turbinella*)
Trees	Low (12%)	Alligator Juniper (*Juniperus deppeana*) Pinyon Pine (*Pinus edulis*)	Arizona Walnut (*Juglans major*) Arizona Sycamore (*Platanus wrightii*) Fremont Cottonwood (*Populus fremontii*)
All	Low (6%)	Trees	Graminoids (mostly grasses) Forbs

1. Forbs include all herbaceous flowering plants and graminoids include all grasses, sedges, and rushes.
2. Similarity to site potential is a nominal classification: low (0 to 33 percent), moderate (34 to 66 percent), and high (67 to 100 percent).

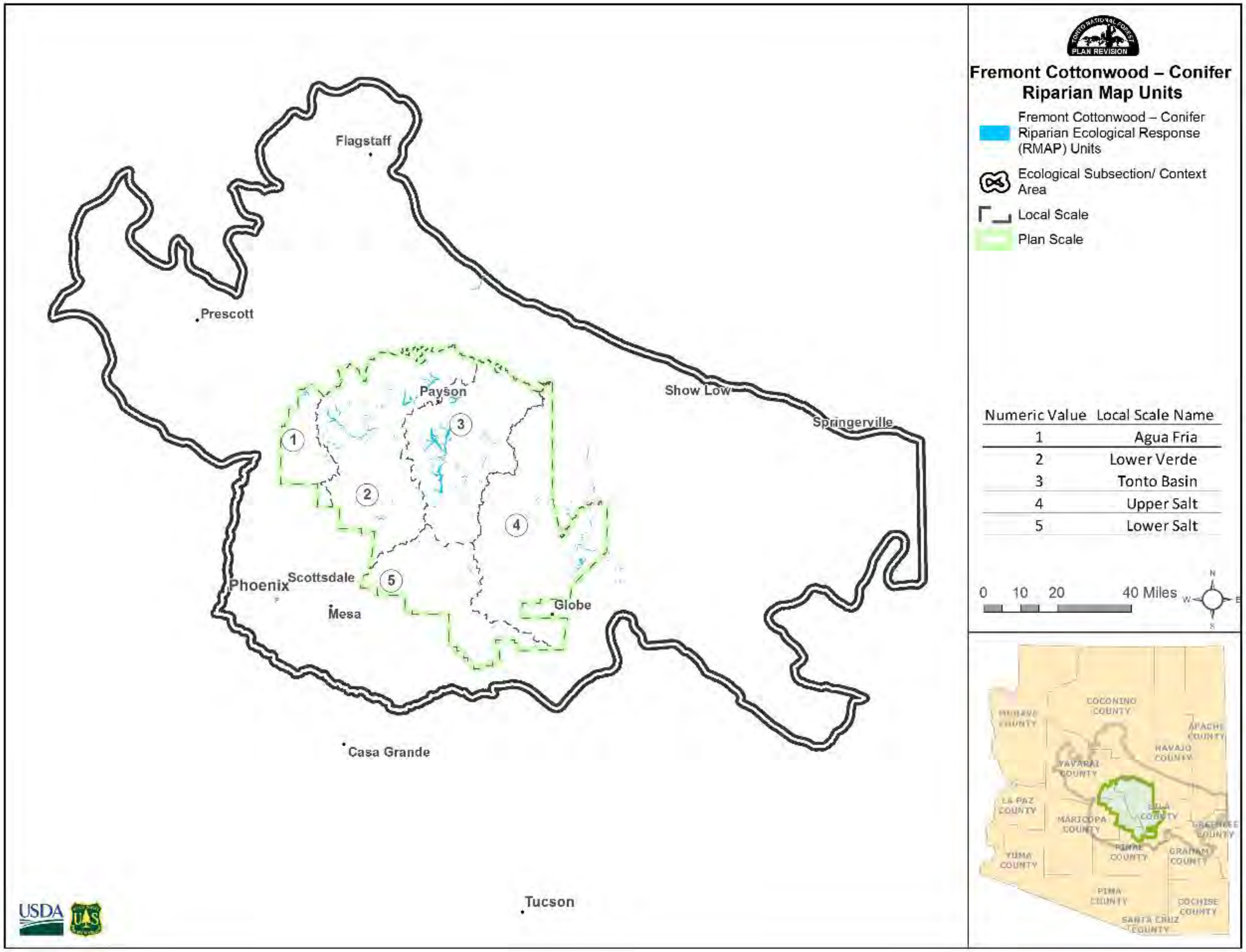


Figure 26. Fremont Cottonwood-Conifer riparian map units

Vegetative Groundcover

Groundcover is similar to reference conditions. While the ecological status analysis shows high departure in species composition and community structure, there is moderate vegetative groundcover (67 percent similarity to reference conditions) – most likely the result of adequate or abundant litter (for example, fine downed woody material) in addition to vegetative cover.

Upland Condition

Uplands with degraded ecological conditions are more prone to uncharacteristic wildfire that can have negative effects on the adjacent riparian systems. While degraded upland conditions do not always result in direct impacts to riparian areas (high moisture content), they can indirectly affect the discharge, timing, or duration of streamflow events and the amount of sediment supplied to a riparian area. In general, risk to riparian areas has increased as a result of active fire suppression and exclusion at the watershed level. Historically, vegetation near riparian zones were structured in a mosaic-like pattern with patches of vegetation creating breaks in fuel continuity. Current conditions show high fuel loads and large patch sizes at the riparian corridor, increasing the risk of flooding and sedimentation (specifically at higher elevations with high erosion hazards) at the Fremont Cottonwood-Conifer ecological response unit. This is supported by the high number of upland acres classified with moderate to high departure in fire regime (fire regime condition class II and fire regime condition class III). While projections show some improvements (high to moderate seral state departure), risk of wildfire to riparian areas is still moderate after 100 years under current management. This is due to the large amounts of coarse woody debris and high stand densities on the landscape.

Table 50. Upland condition analysis for Fremont Cottonwood-Conifer ecological response unit (ERU)

Dominate Adjacent upland vegetation/ERUs at Riparian Corridor*	Averaged Current Seral State departure for Adjacent ERUs**	Averaged 100-year Projection of Seral State departure for Adjacent ERUs**	Percent acres by Fire Regime Condition Class for Adjacent ERUs**
Juniper Grass, Pinyon-Juniper Woodland and Semi-Desert Grassland ERUs	High (77)	Moderate (56)	FRCC I (low departure): 6 percent FRCC II (moderate departure): 80 percent FRCC III (high departure): 14 percent

* Upland condition is evaluated for each riparian ecological response unit by analyzing the top 2 to 3 dominant adjacent vegetation/ecological response units by area within the riparian corridor (¼-mile buffer).

** Seral state departure (current and 100-year projection) values and current fire regime condition class values for adjacent ecological response units are area weighted by riparian corridor to derive upland condition score/departures.

Key Trends

Risk to the ecological integrity of this ecological response unit is moderate as 56 percent of streams are rated as impaired, and 24 are rated as unstable. However, the opportunity for restoration is high because stream reaches in impaired condition have fairly diverse ecological conditions with the capability of providing improved plant composition and diversity. Therefore only 24 percent of the ecological response unit has the lowest level of plant diversity and ecological integrity compared to the 76 percent with moderate ecological integrity. Additionally the Tonto has a large influence in the sustainability and maintenance of the Fremont Cottonwood-Conifer ecological response unit at the broader landscape and context scale as most context acres are concentrated on the Tonto National Forest. On the Tonto National Forest, the Tonto Basin local scale should be the focus of improving ecological integrity for the ecological response unit. This zone has the highest proportion of Fremont Cottonwood-Conifer ecological response unit acres and streams within this zone are more impaired than the other zones where the Fremont Cottonwood-Conifer ecological response unit is found.

Water control measures (flood timing, magnitude, and frequency) have had significant impacts to cottonwood habitats regionally. Many riparian streams have become highly channelized to reduce overbank flooding and maximize water conveyance to downstream users. These activities and features have led to the alteration of natural hydrologic regimes, which are unsuitable for natural regeneration or maintenance of cottonwood riparian forests. These factors have likely influenced the current conditions for the Fremont Cottonwood-Conifer ecological response unit where there is a low abundance of vernal flood-adapted species, such as Fremont cottonwood (*Populus fremontii*). Drought and changes in water supplies (including surface and subsurface flows) have also likely influenced the current conditions (drier conditions). This is evident by the shift in abundance from mesic to xeric species (ecological status analysis). Much of this ecological response unit is found at mid to high elevations (average elevation of 3,279 feet) where the adjacent vegetation is at high risk of catastrophic fires – increasing the risk of flooding and sedimentation at Fremont Cottonwood-Conifer riparian areas.

Cottonwood Group

Elevational range on the Tonto: 1,306 – 6,962 feet. **Average elevation**: 2,972 feet

Photo 15. Representative images of the Cottonwood Group ecological response unit

The cottonwood group includes Narrowleaf Cottonwood/Shrub, Sycamore-Fremont Cottonwood, Fremont Cottonwood/Shrub, and Fremont Cottonwood/Oak riparian ecological response units. Riparian species commonly found in the Cottonwood Group ecological response unit group are Fremont cottonwood (*Populus fremontii*), narrowleaf cottonwood (*P. angustifolia*) and lanceleaf cottonwood (*P.* × *acuminata*), boxelder (*Acer negundo*), willow species (*Salix* spp), Arizona alder (*Alnus oblongifolia*), Arizona Sycamore (*Platanus wrightii*), velvet ash (*Fraxinus velutina*), Arizona walnut (*Juglans major*) and desert willow (*Chilopsis linearis*). Mesquite bosques and forests (*Prosopis* spp.) are also a subtype for some mapped riparian areas within this ecological response unit.

This collective group of ecological response units represents a diverse assemblage of riparian vegetation, mapped from 1,306 feet to 6,962 feet on the Tonto National Forest. Many of these riparian species have unique adaptations or strategies that allow them to persist in these high disturbance (flooding) environments. These plant strategies include the production of a large numbers of small seeds in high-frequency disturbance environments, the ability to establish from broken branches and take root, ability to colonize freshly deposited alluvium or seed beds and ability to withstand some fire. The range of plant strategies (functional types), species diversity, and flow characteristics (surface and subsurface) has a high influence on the ecological integrity of riparian systems. Maintaining a range of functional types is paramount to insuring these systems are resilient to a range of climatic conditions and disturbances.

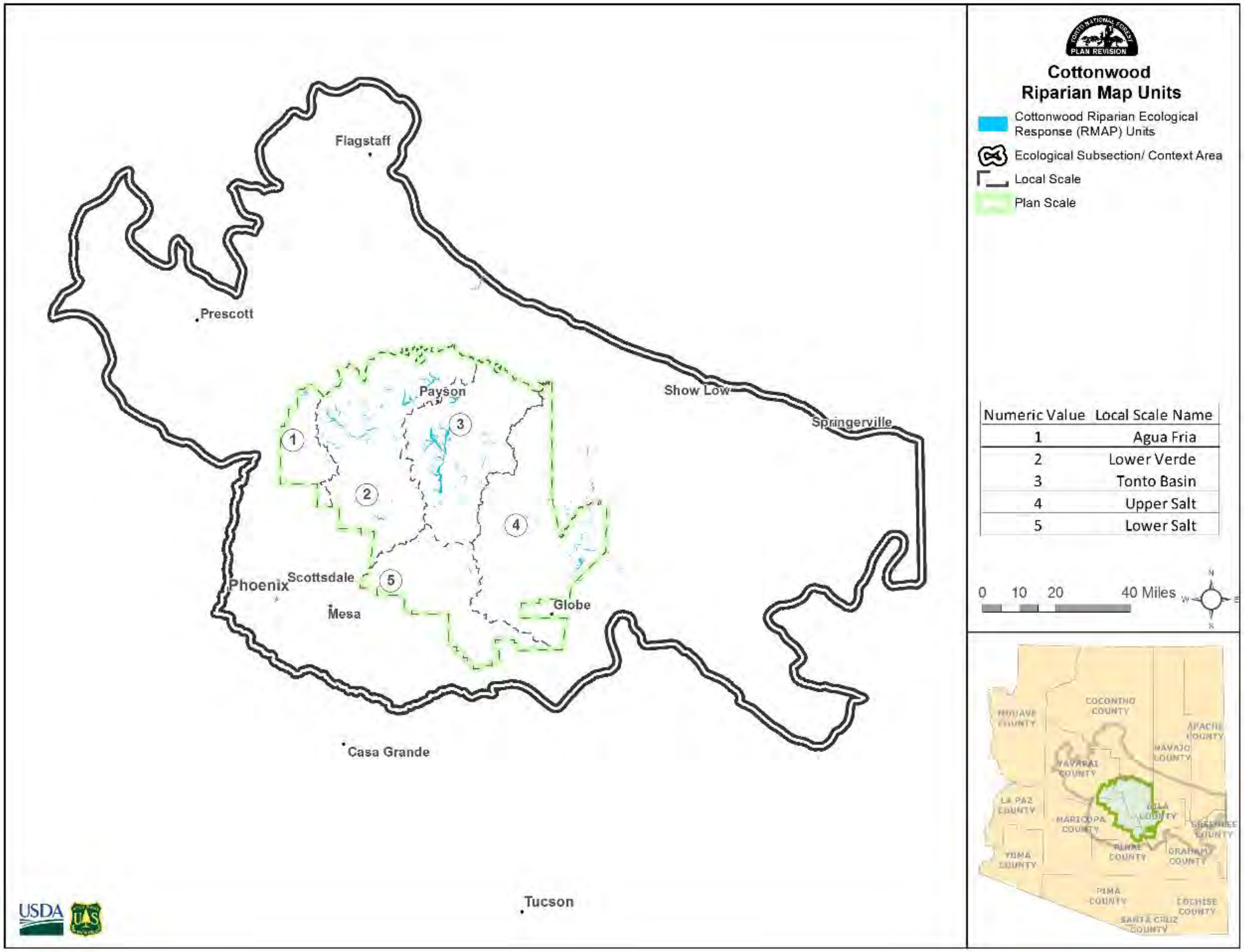
Distribution and Representation

The Cottonwood Group ecological response unit is the most abundant riparian ecological response unit on and off the Tonto National Forest. On the Tonto, this ecological response unit makes up 67 percent of all riparian ecological response units. It is fairly well distributed across all local scales, with the highest proportion of Cottonwood ecological response unit acreage at the Upper Salt and Agua Fria zones. Figure 27 displays the general location of the Cottonwood Group ecological response unit within the context area and the Tonto National Forest. The opportunity for the Tonto National Forest to contribute to the ecological integrity of this ecological response unit at the broader landscape scale (context area) is moderate as 57,063 of the 124,568 acres (46 percent of the context acres) are located on the Tonto (table 51).

Table 51. Distribution of Cottonwood Group (acres and percent) at context, plan, and local scales

Acres Measured	Context	Tonto National Forest	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Cottonwood Group acres	124,568	57,063	1,825	17,211	11,896	20,547	5,584
Total RMAP acres*	186,611	84,777	2,318	26,861	22,327	25,427	7,843
Cottonwood Group Percent of Analyzed RMAP acres*	67%	67%	79%	64%	53%	81%	71%

* These acres only include the riparian mapping project (RMAP) units analyzed in this assessment: Desert Willow, Fremont Cottonwood-Conifer, Cottonwood Group, and Ponderosa Pine/Willow ecological response units.



Numeric Value	Local Scale Name
1	Agua Fria
2	Lower Verde
3	Tonto Basin
4	Upper Salt
5	Lower Salt

Figure 27. Cottonwood Group riparian map units

Key Riparian Ecosystem Characteristics

Riparian Condition

The proportion (33 percent) of unstable streams for this ecological response unit are nearly equal to the proportion of unstable streams forest-wide (31 percent). While the analysis of riparian condition by ecological response unit is restricted to the plan area and forest boundary, the Upper Salt zone has the highest proportion of unstable and impaired streams where the Cottonwood Group ecological response unit is the most abundant (81 percent of riparian acres) on the Tonto.

Table 52. Riparian condition by Cottonwood Group Riparian ecological response unit and streams by local and plan scales

Riparian Condition Class	Riparian Condition (percent) by Riparian ERU (plan scale)	Riparian Condition (percent) for all Analyzed Streams by Plan and Local Scale					
	Cottonwood Group ERU	Plan Scale	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Unstable	33	31	24	28	37	30	42
Impaired	50	51	25	51	49	62	32
Stable	17	18	51	21	14	8	26

* Riparian condition is analyzed by riparian ecological response unit at the plan scale by intersecting Tonto stream assessment data by riparian ecological response unit. Reference “Tonto Stream Assessment” section in the introduction for more information.

** Riparian condition is assessed for all streams by local scale and not for riparian ecological response unit by local scale because the stream assessment data is not sufficiently distributed across the Tonto to do such analysis.

Ecological Status (Similarity to Site Potential)

Ecological status for the Cottonwood Group ecological response unit is moderately departed from reference as only 32 percent similarity exists between the potential natural community and the current plant community. Overall, increases in shrubs and grasses are influencing the dissimilarity in site potential. Exotic and invasive grass species, such as red brome (*Bromus rubens*) and Bermuda grass (*Cynodon dactylon*), are overabundant while native grasses, such as deer grass (*Muhlenbergia rigens*), are poorly represented. While grass abundance is actually higher than reference conditions, species diversity at sites may be lower due to the overall poor representation of native species. In general, there is a greater abundance of non-hydrophytic plants (those growing in drier conditions) than hydrophytic plants (those growing in saturated to wet soil conditions). A number of functionally important riparian species; such as seep willow (*Baccharis salicifolia*), goodings willow (*Salix gooddingii*) and Arizona sycamore (*Platanus wrightii*), are poorly represented at several locations. These species help stabilize stream banks, help slow water velocity, and decrease the erosive power of flood flows. They also provide important structural diversity for wildlife habitat. Velvet mesquite (*Prosopis velutina*) tends to occur further from the low flow channel (generally below the water table and in contact with the saturated zone) at higher terraces and along intermittent and ephemeral reaches. The overabundance of mesquite (*Prosopis* spp.) also indicates a shift towards drier conditions at sites.

Table 53. Cottonwood Group ecological response unit lifeform and overall similarity to site potential (percent similarity)

Lifeform[1]	Similarity to Site Potential (percent)[2]	Species and Lifeforms Over-represented	Species and Lifeforms Under-represented
Forbs	Low (17%)	Yellow Sweetclover (*Melilotus officinalis*) Common Horestail (*Equisetum arvense*)	Hoary Bowlesia (*Bowlesia incana*) Shrubby Deervetch (*Lotus rigidus*)
Graminoids	Moderate (36%)	Red Brome (*Bromus rubens*) Bermuda Grass (*Cynodon dactylon*) Mouse Barley (*Hordeum murinum*)	Deer Grass (*Muhlenbergia rigens*) Arizona Fescue (*Festuca arizonica*)
Shrubs	Moderate (45%)	Desert Broom (Baccharis sarothroides) Turpentine Bush (Ericameria laricifolia)	Seep-willow (Baccharis salicifolia) Sacred Datura (*Datura wrightii*)
Trees	Moderate (60%)	Arizona Alder (Alnus oblongifolia) Velvet Mesquite (*Prosopis velutina*)	Arizona Sycamore (*Platanus wrightii*) Goodings Willow (*Salix gooddingii*)
All	Low (32%)	Shrubs Graminoids (mostly grasses) Trees and Forbs slightly over	None

1. Forbs include all herbaceous flowering plants and graminoids include all grasses, sedges, and rushes.
2. Similarity to site potential is a nominal classification: low (0 to 33 percent), moderate (34 to 66 percent), and high (67 to 100 percent).

Vegetative Groundcover

Groundcover is very similar (73 percent) to reference conditions however some areas do have impaired soil conditions that are affecting site productivity. For example, several areas within this ecological response unit lack well-developed surface roots, biotic soils crusts, and litter indicating impaired site conditions.

Upland Condition

Uplands with degraded ecological conditions are more prone to uncharacteristic wildfire that can have negative effects on the adjacent riparian systems. While degraded upland conditions do not always result in direct impacts to riparian areas, they can indirectly affect the discharge, timing, or duration of streamflow events, and the amount of sediment supplied to a riparian area.

Risk from wildfires has increased as a result of active fire suppression and exclusion in the adjacent communities. Historically, vegetation near riparian zones were structured in a mosaic-like pattern with patches of vegetation, creating breaks in fuel-continuity. With increased fuel loads and large patch sizes, fires are more likely to burn through the riparian corridor. Large wildfires can also increase flooding and subsequent loss of riparian vegetation. This is supported by the high number of upland acres classified with moderate to high departure in fire regime (fire regime condition class II and fire regime condition class III). Adjacent vegetation is projected to increase from moderate departure to high departure (seral state departure) as a result of large amounts of coarse woody debris and high stand densities – all of which will increase risk to nearby riparian areas.

While there is little quantitative data on the fire ecology (fire return intervals, frequency, and intensity) of riparian areas, riparian vegetation likely experienced fire more often along grassland

and savanna ecosystems and less at chaparral and desert shrublands and conifer forests (Skinner and Chang 1996). Thirty four percent of the riparian corridor for this ecological response unit consists of grassland and savanna ecosystems (Semi-Desert Grassland, Juniper Grass, and Pinyon Juniper Grass ecological response units) while 46 percent consist of chaparral and desert Shrublands (Interior Chaparral and Mojave Sonoran Desert Scrub ecological response units). A number of woody shrub species, such as willows (*Salix* spp.), in this ecological response unit show some recovery from fires by their ability to resprout. However, fires do not result in population renewal (that is, create opportunities for the establishment of new individuals) for these species as it does for fire-adapted species (for example, species that have seeds that germinate following high temperatures from fires). Other dominant species for this ecological response unit, such as Fremont cottonwood (*Salix gooddingii*), rarely resprout and experience moderate to high mortality following light and severe burns (Stuever 1997).

Table 54. Upland condition analysis for Cottonwood Group ecological response unit

Dominate Adjacent upland vegetation/ERUs at Riparian Corridor*	Averaged Current Seral State departure for Adjacent ERUs**	Averaged 100-year Projection of Seral State departure for Adjacent ERUs**	Percent acres by Fire Regime Condition Class values for Adjacent ERUs**
Mojave-Sonoran Desert Scrub, Juniper Grass and Semi-Desert Grassland ERUs	Moderate (46)	High (69)	FRCC I (low departure): 23 percent FRCC II (moderate departure): 39 percent FRCC III (high departure): 41 percent

* Upland condition is evaluated for each riparian ecological response unit by analyzing the top 2 to 3 dominant adjacent vegetation/ecological response units by area within the riparian corridor (¼-mile buffer).

** Seral state departure (current and 100-year projection) values and current fire regime condition class values for adjacent ecological response units are area weighted by riparian corridor to derive upland condition score/departures.

Key Trends

Risk to the ecological integrity of this ecological response unit is high as only 17 percent of streams are rated stable. However, the opportunity for restoration is high because stream reaches in impaired condition (50 percent) provide fairly diverse ecological conditions but have the capability of providing improved plant composition and diversity and quality riverine habitat. Therefore only 33 percent of the ecological response unit has the lowest level of plant diversity and ecological integrity. Risk is especially high at the Lower Salt zone on the Tonto for several reasons. The Cottonwood ecological response unit represents 81 percent of all riparian ecological response unit acres at the Lower Salt zone which contains the largest number of unstable streams than any other local scale on the Tonto National Forest. Also, this zone is close to the Phoenix metropolitan area where stressors such as heavy recreational use (off-highway vehicle use and user-created trails in riparian areas) and other activities (mining, road construction, grazing) are highly concentrated. Competing demands from multiple uses and impacts are most concentrated at these riparian areas.

Evidence of impaired conditions include the lack of well-developed surface roots and intact soil crusts (vegetative groundcover analysis), reduction in native grass and forb species abundance and shifts in abundance to exotic grasses (ecological status analysis), and degraded upland conditions capable of negatively impacting the nearby riparian areas (upland condition analysis). While some species in this ecological response unit are capable of some post-fire recovery (willows, *Salix* spp.), in general, the increased fuel loads at the surrounding uplands coupled with stressed conditions (lowered site productivity, moisture deficits) and foreseeable stressors (climate change) on the Tonto National Forest are likely to result in lower structural diversity, lower species diversity (fewer riparian wetland-obligate species) and reduced ecological integrity for the Cottonwood Group riparian ecological response unit.

Water control measures (flood timing, magnitude, and frequency) have had significant impacts to cottonwood habitats on the Tonto National Forest and regionally. Many riparian streams have become highly channelized to reduce overbank flooding and maximize water conveyance to downstream users. These activities and features have led to the alteration of natural hydrologic regimes, which are unsuitable for the natural regeneration and maintenance of a number of important wetland-obligate riparian species (such as Fremont cottonwood, *Populus fremontii,* and Goodings willow, *Salix gooddingii*). Current conditions show reductions in these key riparian species (ecological status analysis). Although not detected in the terrestrial ecological unit inventory plot data for the ecological analysis, tamarisk (*Tamarix chinesnsis*) is present at low levels (mostly scattered populations) at river segments of this ecological response unit, primarily along the Verde River and some stretches of the Lower Salt River. Several native riparian taxa, such as cottonwood and willow, tolerate a much smaller range of depth to groundwater than tamarisk. Tamarisk generally remains subdominant if site conditions are supporting healthy native riparian tree species. Tamarisk does not reach high densities on the Tonto as it does at other locations (for example, lower Colorado River, lower Gila River). Several stretches of the lower Salt River have high stand densities of tamarisk but mainly downstream off the Tonto National Forest. Tamarisk dominance over native taxa tends to occur on rivers with large departures in flow regimes – such as deeper groundwater levels, larger fluctuations in groundwater, and intermittent stream flows (Stromberg et al. 2005). Therefore, tamarisk dominance should be viewed as an indicator of degrading riparian conditions instead of the primary cause of degradation. Additionally, the management of this species requires site-specific analysis as it has become habitat for some endangered or sensitive species, such as the southwestern willow flycatcher (*E. t. extimus*).

Ponderosa Pine/Willow

Elevational range on the Tonto: 4,436 – 7,044 feet. **Average elevation:** 5,679 feet.

Ponderosa Pine/Willow is typically found at elevations ranging from 4,500 to 9,700 feet and is characterized by an overstory of ponderosa pine with an understory of shrub-form willow species. As a result of the pine overstory, this map unit is particularly hard to distinguish from pine-oak systems of similar physiognomy and is believed to be under-represented in the mapping. Other riparian species commonly found in this ecological response unit include oneseed juniper (*Juniperus monosperma*) and Arizona white oak (*Quercus arizonica*), Arizona walnut (*Juglans major*), box elder (*Acer negundo*), and velvet ash (*Fraxinus velutina*).

Photo 16. Ponderosa Pine/Willow ecological response unit

Distribution and Representation

The Ponderosa Pine/Willow ecological response unit makes up 4 percent of analyzed riparian ecological response unit acreage (least abundant ecological response unit) at the context scale. On the Tonto, this ecological response unit is also the least abundant, making up 7 percent of all analyzed riparian ecological response units. This ecological response unit is found only at the Lower Verde, Tonto Basin, and Upper Salt local zones and is most abundant at the Lower Verde (14 percent of riparian acres). Figure 28 displays the general location of the Ponderosa Pine/Willow ecological response unit within the context area and the Tonto National Forest. The opportunity for the Tonto National Forest to contribute to the ecological integrity of this ecological response unit at the broader landscape scale (context area) is high as 6,063 of the 7,146 acres (85 percent of the context acres) are located on the Tonto (table 55).

Table 55. Distribution of Ponderosa Pine/Willow (acres and percent) at context, plan, and local scaless

Acres Measured	Context	Tonto National Forest	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Ponderosa Pine/Willow acres	7,146	6,063	--	3,686	2,234	143	--
Total RMAP acres*	186,611	84,777	2,318	26,861	22,327	25,427	7,843
Ponderosa Pine/Willow Percent of Analyzed RMAP acres*	4%	7%	--	14%	10%	1%	--

* These acres only include the riparian mapping project (RMAP) units analyzed in this assessment: Desert Willow, Fremont Cottonwood-Conifer, Cottonwood Group, and Ponderosa Pine/Willow ecological response units.

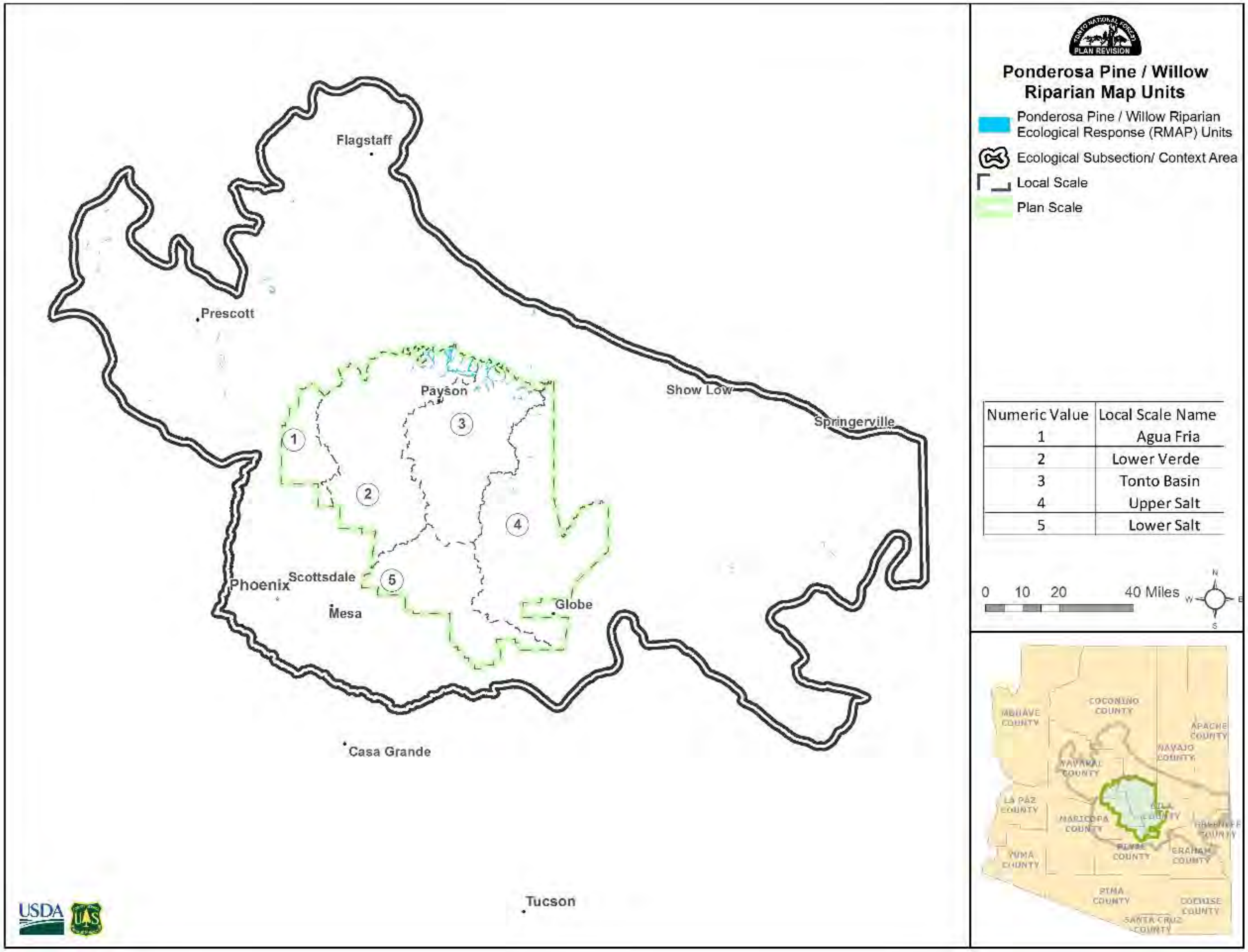


Figure 28. Ponderosa Pine/Willow riparian map units

Key Riparian Ecosystem Characteristics

Riparian Condition

The Ponderosa Pine/Willow ecological response unit has the lowest proportion of unstable streams compared to the other riparian ecological response units and a lower proportion (20 percent) of unstable streams than overall stream conditions forestwide (31 percent). Overall riparian stream conditions at the Lower Verde zone (where the Ponderosa Pine/Willow ecological response unit is most abundant) closely matches overall stream conditions forestwide with slightly more streams rated stable. Riparian conditions are more impaired at the Tonto Basin zone where the Ponderosa Pine/Willow ecological response unit is the 2nd most abundant on the Tonto.

Table 56. Riparian condition by Ponderosa Pine/Willow riparian ecological response unit and streams by local and plan scales

Riparian Condition Class	Riparian Condition (percent) by Riparian ERU (plan scale)	Riparian Condition (percent) for all Analyzed Streams by Plan and Local Scale					
	Ponderosa Pine/Willow ERU	Plan Scale	1 Agua Fria	2 Lower Verde	3 Tonto Basin	4 Upper Salt	5 Lower Salt
Unstable	20	31	24	28	37	30	42
Impaired	57	51	25	51	49	62	32
Stable	23	18	51	21	14	8	26

* Riparian condition is analyzed by riparian ecological response unit at the plan scale by intersecting Tonto stream assessment data by riparian ecological response unit. Reference “Tonto Stream Assessment” section in the introduction for more information.

** Riparian condition is assessed for all streams by local scale and not for riparian ecological response unit by local scale because the stream assessment data is not sufficiently distributed across the Tonto to do such analysis.

Ecological Status (Similarity to Site Potential)

Ecological status for the Ponderosa Pine/Willow ecological response unit is moderately departed from reference conditions as only 34 percent of similarity exists between the potential natural community and the current plant community. However, this ecological response unit has the highest level of similarity to site potential than any of the other riparian ecological response units analyzed on the Tonto National Forest. The overall increase in shrubs, and to some degree grasses and forbs, is influencing departure from reference conditions. While a moderate representation of grasses indicate productive and healthy riparian areas, species diversity may be lower at sites as several important native grasses, such as sideoats grama (*Bouteloua curtipendula*), are poorly represented overall. The low forb similarity is largely a result of the complete absence of some forbs and large increases in others, such as common yarrow (*Achillea millefolium*). Some areas have more juniper (*Juniperus* spp.) and oak (mainly Emory oak, *Quercus emoryi*), but these species are not atypical of this riparian ecological response unit. With the exception of the slight increases of some species that tend to occupy drier sites, such as Acacia and Manzanita, the moderate representation and abundance of native species suggest local site conditions (available plant moisture) are more or less within the range of conditions necessary to support riparian vegetation and ecological health.

Table 57. Ponderosa Pine/Willow ecological response unit lifeform and overall similarity to site potential (percent similarity)

Lifeform[1]	Similarity to Site Potential (percent)[2]	Species and Lifeforms Over-represented	Species and Lifeforms Under-represented
Forbs	Low (7%)	Common Yarrow (*Achillea millefolium*) *Lotus spp*.	*Eriogonum spp.*
Graminoids	Moderate (37%)	Squirreltail (*Elymus elymoides*) Hairy Grama (*Bouteloua hirsuta*) Blue Grama (*Bouteloua gracilis*)	Desert Needlegrass (*Achnatherum speciosum*) Sideoats Grama (*Bouteloua curtipendula*)
Shrubs	Moderate (65%)	Manzanita (*Arctostaphylos pungens*) Skunkbush (*Rhus trilobata*) Fern Acacia (*Acacia angustissima*)	Sonoran Scrub Oak (*Quercus turbinella*) Mountain Mahogany (*Cercocarpus mountanus*)
Trees	Moderate (57%)	Alligator Juniper (*Juniperus deppeana*) Emory Oak (*Quercus emoryi*)	Ponderosa Pine (*Pinus ponderosa*)
All	Moderate (34%)	Graminoids (mostly grasses) Shrubs Forbs slightly over	Trees

1. Forbs include all herbaceous flowering plants and graminoids include all grasses, sedges, and rushes.
2. Similarity to site potential is a nominal classification: low (0 to 33 percent), moderate (34 to 66 percent), and high (67 to 100 percent).

Vegetative Groundcover

Groundcover matches (100 percent similarity) reference conditions, indicating a sufficient amount of vegetation and litter.

Upland Condition

Uplands with degraded ecological conditions are more prone to uncharacteristic wildfire that can have negative effects on the adjacent riparian systems. While degraded upland conditions do not always result in direct impacts to riparian areas, they can indirectly affect the discharge, timing, or duration of streamflow events, and the amount of sediment supplied to a riparian area. Risk from wildfires has increased as a result of active fire suppression and exclusion in the adjacent communities. Historically, vegetation near riparian zones were structured in mosaic-like patterns with patches of vegetation creating breaks in fuel-continuity. With increased fuel loads and large patch sizes, fires are more likely to burn through the riparian corridor. Large wildfires can also increase flooding and subsequent loss of riparian vegetation. While there is little quantitative data on the fire ecology (fire return intervals, frequency, and intensity) of riparian areas, riparian vegetation likely experienced fire more often along grassland and savanna ecosystems and less at chaparral and desert shrublands and conifer forests (Skinner and Chang 1996). Ponderosa pine forests (Ponderosa Pine - Evergreen Oak ecological response unit) and mixed conifer (Mixed Conifer - Frequent Fire ecological response unit) dominate the riparian corridor of this ecological response unit.

Risk from wildfire is high for this ecological response unit as a high percentage of the upland vegetation is at an increased risk of altered fire behavior (93 percent of acres classified in fire regime condition class II and fire regime condition class III). Fires in these ecosystems are burning at higher severities than reference conditions. The Ponderosa Pine/Willow ecological response unit is located within ponderosa pine forests where large catastrophic fires, such as the 1990 Dude Fire, have had lasting effects on the landscape. Willows (*Salix* spp.), the dominant understory species for this ecological response unit, show some recovery from fires by their ability to resprout. However, fires do not encourage population renewal (that is, create opportunities for the establishment of new individuals) for these species as it does for fire-adapted species (for example, species with seeds that germinate following high temperatures from fires). While projections show some improvements (high to moderate departure in seral state departure), risk of wildfire to riparian areas is still moderate after 100 years under current management. This is due to the large amounts of coarse woody debris and high stand densities on the landscape.

Table 58. Upland condition analysis for Ponderosa Pine/Willow ecological response unit

Dominate Adjacent upland vegetation/ERUs at Riparian Corridor*	Averaged Current Seral State departure for Adjacent ERUs**	Averaged 100-year Projection of Seral State departure for Adjacent ERUs**	Percent acres by Fire Regime Condition Class values for Adjacent ERUs**
Ponderosa Pine Evergreen Oak and Mixed Conifer-Frequent Fire ERUs	High (70)	Moderate (49)	FRCC I (low departure): 7 percent FRCC II (moderate departure): 46 percent FRCC III (high departure): 47 percent

* Upland condition is evaluated for each riparian ecological response unit by analyzing the top 2 to 3 dominant adjacent vegetation/ecological response units by area within the riparian corridor (¼-mile buffer).

** Seral state departure (current and 100-year projection) values and current fire regime condition class values for adjacent ecological response units are area weighted by the riparian corridor to derive upland condition score/departures.

Key Trends

While the mapping of riparian ecological response units is limited at the context scale, based on current mapping the Tonto National Forest has a high influence on the sustainability and maintenance of the Ponderosa Pine/Willow riparian ecological response unit as 85 percent of the context acres are on the Tonto. Current conditions are not as impaired for this ecological response unit as for other ecological response units. This is evident by the lower proportion of impaired and unstable streams (riparian condition analysis) and moderate representation of riparian vegetation (ecological status analysis). Additionally, the opportunity for restoration is high because over half the streams for this ecological response unit on the Tonto are rated as impaired (riparian condition analysis). Stream reaches in impaired condition provide fairly diverse ecological conditions but have the capability of providing improved plant composition, species diversity, and quality riverine habitat. Only 20 percent of this ecological response unit is rated as unstable. Therefore, only 20 percent has the lowest level of plant diversity and ecological integrity.

Risk to the ecological integrity for the Ponderosa Pine/Willow ecological response unit is higher at the Tonto Basin zone and lower at the Lower Verde zone. Over half (61 percent) of the Ponderosa Pine/Willow ecological response unit acres are located at the Lower Verde zone where overall riparian conditions (all analyzed streams) are much better than the other local zones on the Tonto. The Tonto Basin zone has the second most degraded riparian conditions (86 percent of streams are impaired and unstable) forestwide and 37 percent of the Ponderosa Pine/Willow ecological response unit acres are located at this zone.

Some streams in this ecological response unit are subject to recreational impacts (especially along the Mogollon Rim), however a number of streams are located in inaccessible areas with steep terrain. Perhaps the biggest stressor for this ecological response unit is catastrophic wildfires occurring at the surrounding uplands and watersheds. Current and projected conditions show highly stressed uplands (Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units) with high fuel loads. While willow shrub species (*Salix* spp.), the dominant understory species for this ecological response unit, show some recovery from fires they are not fire-adapted species. In addition to the indirect impacts of fire (increased flooding and sedimentation), potential direct impacts to riparian vegetation ecosystems include reduced site productivity (loss of soils and key riparian species) and lowered structural diversity. These impacts are more pronounced at areas experiencing drier conditions (lower moisture content, more susceptible to burning). The interaction of increasing occurrences of catastrophic wildfires and climate change impacts (drying conditions and increased flooding) are likely to further stress these riparian systems.

Risk to Ecological Integrity of Riparian Ecosystems

For this assessment, risk is a direct interpretation of departure. Risk is defined here by the likelihood and severity of negative ecological outcomes. First, an analysis of stream bank stability of riparian ecosystems on the Tonto National Forest is presented. Second, risk to key riparian ecosystem characteristics and the impacts on the ecological integrity of riparian ecological response units is discussed. The last section concludes with the overall risk to riparian ecosystems on the Tonto National Forest (incorporating the analyses from sections one and two).

Analysis of Riparian Vegetation on Stream Bank Stability and Ecological Integrity

Riparian vegetation can have varying degrees of influence on the stability of riparian ecosystems. In addition to riparian vegetation, other key factors that influence stability include the stream morphology, geomorphology, and hydrology (surface and subsurface flows, flood frequency, timing, and magnitude). Sampled streams on the Tonto National Forest have been inventoried following the Rosgen (1996) stream classification. Table 59 describes the Rosgen (1996) stream type, description of key processes, proportion of stream types on the Tonto, and the influence of riparian vegetation on stream bank stability by stream type. While healthy riparian vegetation is critical for all riparian systems, this analysis highlights the stream types and proportions on the Tonto where riparian vegetation has a disproportionate influence on key ecosystem processes. A specific stream type may rely on woody streambank vegetation for stream bank stability (for example, low-elevation riparian areas with wide floodplains) more than another stream type (for example, canyon settings with large boulders).

Fifty percent of the classified streams types (B, Bc, and C) have moderate to high sensitivity to impacts. The riparian areas consists of narrow, gently sloping valleys with moderately sized floodplains and broad valleys with terraces and alluvial soils with larger floodplains. These riparian areas are more influenced by negative impacts because they generally occur at low to mid elevations where most impacts are concentrated. Riparian bank vegetation is an important component of the stability of these streams, and over 55 percent of these stream types are rated as impaired. Maintaining a diversity of bank-stabilizing species for these riparian areas should be considered in the development of the Forest Plan. Other streams are inherently unstable by definition (D, F) and make up roughly 42 percent of the assessed streams. Some reaches of these streams are showing signs of recovery (floodplain building) and it is suspected that a number of these streams were stable with more developed floodplains (similar to C-type streams) at one time.

Table 59. Rosgen stream type, description, percent of all classified streams on the Tonto and influence of riparian vegetation on stream bank stability

Stream Type	Description	Percent of classified streams on the Tonto NF	Influence of riparian vegetation on stream bank stability
A	A-type streams are the steep, narrow streams of headwaters. They are typically step/pool systems with large sediments, inherently stable and have a high gradient (greater than 4%).	6	Low
B	B-type streams are moderately entrenched, containing narrow floodplains, and have a moderate gradient (2 to 4%), some inherent stability and moderately sensitive to disturbance.	30	Moderate
Bc	Bc-type streams are moderately entrenched have narrow floodplains (similar to B-type) and a low gradient (similar to C-type). These streams are vulnerable to disturbances.	10	Moderate
C	C-type streams are not entrenched and have very wide floodplains which are able to dissipate flood flows and support extensive riparian areas. They have a low gradient (0 to 2%) and display the typical riffle/pool sequence of a meandering stream. C-type streams are sensitive to any disturbance	10	High
D	D-type streams evolve from a more stable stream type due to some natural or management caused disturbance but widen rather than downcutting. They straighten, steepen, and become braided. Braided streams have more than one channel and may change main channels with each high flow. This results in a loss of riparian vegetation and an unstable floodplain.	8	Low
F	F-type streams are highly entrenched (downcut), with little or no floodplain to dissipate flood flows. Consequently, high flows are concentrated in the stream channel rather than in overbank flow which results in streambank erosion and loss of riparian vegetation. They usually evolve from a more stable stream type due to some natural or management caused disturbance. These stream types are generally unstable and extremely sensitive to disturbance.	34	Low
G	G-type streams are unstable, moderately steep (2 to 4%), entrenched gullies with no access to a floodplain. They evolve from a more stable stream type due to some natural or management caused disturbance. They will continue to widen until they become an F-type stream.	2	Low

Risk to Key Riparian Ecosystem Characteristics

Table 60 displays a risk matrix for riparian ecosystem characteristics. The following describes the analysis methods in deriving risk categories for each ecosystem characteristic:

1. **Riparian condition risk** is a weighted score/calculation where more weight is given to the proportion of streams in unstable rankings (weight of 0.75) and less weight is given to the proportion of streams in impaired rankings (weight of 0.25). Impaired streams are given less weight because they provide a moderate level of diversity with the potential to improve conditions compared to unstable streams. The assigned risk ranking is then based on the final weighted score ranges: 0 to 33 percent (low risk), 34 to 66 percent (moderate risk) and 67 to 100 percent (high risk). Riparian condition risk formula: *Weighted riparian condition score = (proportion of unstable streams x 0.75) + (proportion of impaired streams x 0.25)*
2. **Upland condition risk** is assessed using the weighted upland ecological response unit values within the riparian corridor for each riparian ecological response unit. Ranking is based on the class (fire regime condition classes I, II, and III) with the highest proportion of acres. For example, if the highest proportion of upland acres fall into fire regime condition class II (moderate departure in fire regime) for a given riparian ecological response unit, the upland condition risk ranking is moderate.
3. **Ecological status risk** is the inverse rating of similarity to site potential where low similarity is high risk, moderate similarity is moderate risk, and high similarity is low risk.
4. **Upland condition risk** is the inverse rating of groundcover similarity where low similarity is high risk, moderate similarity is moderate risk, and high similarity is low risk.

Table 60. Risk matrix for riparian ecosystem characteristics

Riparian ERUs	Key Riparian Ecosystem Characteristics and Risk[1]			
	Riparian Condition	Ecological Status	Vegetative Groundcover	Upland Condition
Desert Willow		No Data	No Data	
Fremont Cottonwood-Conifer				
Cottonwood Group				
Ponderosa Pine/Willow				

[1] Risk is a nominal classification: low (0 to 33 percent), moderate (34 to 66 percent), and high (67 to 100 percent)

With the exception of vegetative groundcover, most riparian ecosystem characteristics show moderate to high risk. All vegetative material is considered in the analysis of vegetative groundcover while species composition is not considered. However, both vegetative groundcover and species composition are important components of the ecological health of riparian areas. A number of sites on the Tonto have atypical plant communities compared to the potential plant community (that is, low similarity to site potential) which is likely contributing to impaired and unstable conditions (riparian condition analysis). For example, a number of ecological response units on the Tonto National Forest (Cottonwood Group ecological response unit) have a greater abundance of exotic grasses and forbs that provide sufficient groundcover; however, these species may be impairing ecosystem function (changes in soil moisture retention, lower biodiversity, etc.). The presence or absence of certain species can illuminate changes in local site conditions as riparian species have strong affinities for specific moisture requirements (for example, some are groundwater dependent). In general, there are increases in trees and shrubs, many of which are found more often at drier sites – indicating a trend of drying conditions at sites.

Uplands with degraded ecological conditions that are more prone to uncharacteristic wildfire can have negative effects on adjacent riparian systems. While degraded upland conditions do not always result in direct impacts to riparian areas, they can indirectly affect the discharge, timing, or duration of streamflow events and the amount of sediment supplied to a riparian area. The only ecological response unit with low upland condition risk is the Desert Willow ecological response unit. Desert Willow riparian streams are located within sandy washes (mostly Sonoran Desert Scrub) that are naturally unstable and capable of transporting relatively large volumes of sediment following flood events. Therefore, indirect effects from wildfires in the uplands are unlikely to have significant impacts to Desert Willow riparian areas. Direct impacts from fires are likely minimal and localized. Direct impacts are more likely to occur following droughts (less moisture at the riparian zone) and when the surrounding vegetation is capable of producing large enough fuel loads (for example, dense vegetation with exotic grass component).

Overall Risk to Ecological Integrity of Riparian Ecosystems

Risk Forestwide

Cottonwood ecosystems (Cottonwood Group and Fremont Cottonwood-Conifer ecological response units) are limited in the southwestern United States. They have experienced dramatic reductions over the past century and are at very high risk of degradation on and off the Tonto National Forest from multiple stressors, such as water control efforts, conflicting demands, climate change, and drought. These habitats are some of the most important riparian ecosystems in the Southwest – they are rich in biodiversity and support a number of at-risk species on the Tonto. While the Tonto National Forest does not have a high amount of the Cottonwood Group ecological response unit context acres (that is, low influence on sustainability at the broader landscape scale), this ecological response unit is the most abundant on the Tonto (67 percent of riparian acres).

Water control measures (irrigation diversions, dams, groundwater pumping) have had significant impacts to cottonwood ecosystems (Cottonwood Group, Fremont Cottonwood-Conifer and Ponderosa Pine/Willow ecological response units) regionally and on the Tonto National Forest. Altered flows (timing, magnitude, frequency) have, and continue to have, strong and lasting impacts on these ecosystems. A number of riparian key species are groundwater dependent – some requiring permanent shallow groundwater sources, such as willows (*Salix* spp.) and cottonwoods (*Populus* spp.). Additionally, these riparian species depend on the timing between seed dispersal and the floods that create seedbeds or opportunities for species to establish. Many riparian areas have become altered because flows do not coincide with the phenology (for example, seed dispersal) of the species. This has likely influenced the low abundance of these species on the Tonto (ecological status analysis). Also, without periodic flooding, structural diversity (fewer age groups) is lowered and further reduces ecological integrity. Because riparian species tend to have specific moisture regimes, the presence or absence of certain species can indicate changes in local site conditions. Most of the cottonwood ecosystems (specifically the Cottonwood Group ecological response unit) on the Tonto show an overall reduction in wetland-obligate species (occurs only at wetlands) and increases in facultative upland and upland species (occurs only at uplands). Current conditions show an overabundance of species that tend to occur at drier sites, indicating a shift from mesic/wet to more xeric/dry conditions at locations on the Tonto.

Recreational pressure is an increasing risk to all riparian ecological response units on the Tonto National Forest, especially riparian areas that experience heavy use (Cottonwood Group, Fremont Cottonwood-Conifer and Desert Willow ecological response units). At the watershed level, the high densities of roads have also influenced impaired stream conditions forestwide. Roads directly affect the natural sediment and hydrological regimes by altering stream flow, sediment loading, sediment transport and deposition, channel morphology, channel stability, substrate composition, stream temperatures, water quality, and riparian conditions in the watershed (USDA Forest Service 2000). Also, the high density of user-created trails, trampling, off-highway vehicle use, and herbivory at sites are resulting in impaired riparian conditions. At some areas, fences and enclosures have become damaged (fire, recreation, and fallen trees) where livestock and wildlife (elk) are causing negative impacts to riparian areas (compacted soils and reduced streambank vegetation).

Most riparian ecological response units have low similarity to the potential reference plant community. A number of species have become naturalized in these systems (such as mullein, and sweetclovers) where they have effectively filled in the spaces and are now part of the potential plant community. Other sites are experiencing increases in exotic and invasive species that have strong implications on the stability of riparian ecosystems (for example, increases in surface-rooted grass species and declines in deep-rooted soil binding grass species). Although not detected in the terrestrial ecological unit inventory plot data for the ecological analysis, tamarisk (*Tamarix chinesnsis*) is present in cottonwood habitats (mainly the Cottonwood Group ecological response unit) at low levels, mostly scattered populations primarily along the Verde River and some stretches of the Lower Salt River. When site conditions are not favorable for native riparian taxa (such as willows and cottonwood), tamarisk can rapidly increase and dominate reaches. This tends to occur in rivers with large departures in flow regimes – such as deeper groundwater levels, larger fluctuations in groundwater, and intermittent stream flows (Stromberg et al. 2005). Drying trends, changes in flood frequency, and reductions in native canopy cover can increase the risk associated with tamarisk establishment. Therefore, tamarisk establishment and dominance should be viewed as an indicator species for degrading riparian conditions instead of the primary cause of degradation. Additionally, the management of this species requires site-specific analysis as it has become habitat for some endangered or sensitive species, such as the southwestern willow flycatcher (*E. t. extimus*).

Most mid- to high-elevation riparian areas (Fremont Cottonwood-Conifer, Cottonwood Group and Ponderosa Pine/Willow) are at risk from wildfire effects at the watershed scale. However, cottonwood ecosystems (Fremont Cottonwood-Conifer and Cottonwood Group ecological response units) are likely the most sensitive and at-risk from climate change effects and increased wildfires in the riparian zone as a number of key species for these communities, such as Fremont cottonwood (*Populus fremontii*), are groundwater dependent, easily top-killed, and rarely resprout following fires (not fire-adapted). Risk to the Ponderosa Pine/Willow ecological response unit is moderate to high; however, some willows (*Salix* spp.) show recovery from fire (resprouting) but are not fire-adapted species.

Risk by Local Scale

Forestwide, conditions are most impaired at the Upper Salt, Lower Salt, and Tonto Basin zones (proportion of unstable and impaired streams). Significant amounts of the Desert Willow and Cottonwood Group ecological response unit acres are concentrated at these scales. The Upper Salt zone also has the highest proportion of inventoried C-type streams where riparian vegetation has very strong influence on the stability and ecological integrity of these ecosystems. Risk to these ecological response units at these zones is high, because they border the Phoenix metropolitan area where heavy recreational impacts (roads, user-created trails, off-highway vehicle use) occur. Water withdraws are also of concern as many of these riparian species are groundwater dependent, and projections of increasing aridity, climate change effects and increasing water demands are likely to further exacerbate conditions – specifically among desert riparian ecosystems (Cottonwood Group and Desert Willow ecological response units).

Conditions are less impaired at the Agua Fria and Lower Verde zones (proportion of unstable and impaired streams) with the Agua Fria zone having the highest proportion (51 percent) of stable streams forestwide. A moderate amount of the Pondersoa Pine/Willow and Fremont Cottonwood-Conifer ecological response unit acres are found at these scales. Riparian vegetation has low to moderate influence on stream bank stability in these areas. Some systems have highly entrenched channels with little or no floodplain to dissipate flood flows where riparian vegetation is frequently scoured (F-type streams). Others have wide floodplains which are able to dissipate flood flows and support extensive riparian vegetation (C-type streams). Some of these areas are not as susceptible to negative impacts from recreation as other areas on the Tonto due to their inaccessibility (steep terrain, landscape features, remoteness). However, wildfire risk to riparian ecosystems at these scales (specifically the Fremont Cottonwood-Conifer and Ponderosa Pine/Willow ecological response units) is high from the accumulation of coarse woody debris and high stand densities near the riparian zone and watershed. In particular, risk is especially high for the Fremont Cottonwood-Conifer ecological response unit where dominant wetland-obligate species, like Fremont cottonwood (*Populus fremontii*), are easily killed following fires.

Table 61. Riparian stream condition by local and plan scales and riparian ecological response units

Scale/zone of Analysis and Riparian ERUs	Riparian Stream Condition (percent)		
	Unstable	Impaired	Stable
Aqua Fria zone	24	25	
Lower Salt zone		32	26
Lower Verde zone	28	51	21
Tonto Basin zone	37	49	14
Upper Salt zone	30		8
Forest-Wide Conditions (plan scale)	31	51	18
Desert Willow ERU		19	
Fremont Cottonwood-Conifer ERU	24		20
Cottonwood Group ERU	33	50	17
Ponderosa Pine/Willow ERU	33	50	17

Shaded cells display where conditions are most degraded (unstable and impaired) and most stable among scales of analysis and riparian ecological response units.

Summary and Key Findings

This assessment reviews the best available information at the forest and broader landscape scale, to assess the ecological integrity of the Tonto National Forest's riparian resources under current Forest Plan direction. Ecosystem integrity was assessed by evaluating key characteristics including riparian condition (ecosystem function and integrity), ecological status (vegetation composition and community structure), vegetative groundcover (ecosystem function), and upland condition (wildfire risk).

Riparian areas on the Tonto National Forest are a focal point for humans, wildlife, and livestock activities, as well as groundwater-dependent species. Therefore, both demands and impacts are high. Risk to the ecological integrity of riparian ecological response units is moderate to high across the Tonto. Not all activities and stressors are equally impacting riparian ecological response units on the Tonto. Riparian areas in proximity to urban areas and highly accessible to users tend to have a greater concentration of negative impacts. A significant proportion of the Desert Willow and Cottonwood Group ecological response units are concentrated at such areas on the Tonto (Lower Salt and Upper Salt local zones). Other ecological response units, such as the Fremont Cottonwood-Conifer, Ponderosa Pine/Willow, and Cottonwood Group, are especially sensitive to the compounded effects of drying conditions (climate change and drought), increasing pressure of water demands (surface and subsurface flows), and wildfire risks. These highly impacted locations and sensitive riparian areas and ecological response units should be considered in the development of the forest plan. Wildfire risks are high for a number of riparian areas, mainly at mid- to high-elevation ecological response units (specifically Fremont Cottonwood-Conifer and Ponderosa Pine/Willow) on the Tonto. Post-fire effects can result in excessive erosion, sediment deposition in riparian areas, and negative impacts to wildlife habitat.

Climate change is an emerging stressor that will increase the risk to the ecological integrity of riparian resources on the Tonto National Forest. Riparian ecosystems will experience increases in air and surface water temperatures; alterations in the magnitude, duration, and seasonality of precipitation and run-off; and shifts in reproductive phenology and distribution of plants and animals. Climate change is also projected to lead to increased frequency and severity of extreme weather events (for example, increased flooding). Because of the scarcity of water resources in the Southwest, the Tonto National Forest has a significant responsibility for managing and maintaining the ecological integrity and sustainability of riparian ecosystems. Surface flows are intricately connected to subsurface flows and water withdraws off the Tonto National Forest can negatively impact riparian vegetation on the Tonto. The high demands of water resources from local state and regional levels increase the risk of water resources on the Tonto. These demands will also increase as climate change projections of increasing aridity and drought further stress these ecosystems (IPCC 2007; Seager et al. 2007). While climate conditions, drought, and water allocation are outside the scope of forest management, the Tonto can look for opportunities to monitor climate change influences and reduce the risk of riparian ecosystems by considering the key characteristics and their status identified at the project level.

Riparian restoration and maintenance should be focused on restoring healthy functioning ecosystems. Additionally, Tonto National Forest personnel should consider novel ecosystems (atypical plant and animal communities including exotics and invasives) and their impact on ecological integrity with current and foreseeable stressors. Current conditions show a large proportion unstable and impaired stream conditions on the Tonto. However, stream reaches with impaired conditions provide fairly diverse ecological conditions but have the capability of providing improved plant composition and diversity and quality riverine habitat compared to unstable streams. Riparian areas with unstable streams are more likely to have degraded conditions and therefore are less capable of recovery. Therefore the opportunity to restore riparian areas on the Tonto National Forest is high as nearly half of the assessed streams are in impaired conditions and another 18 percent are stable.

Chapter 6. Watersheds and Water Resources

Introduction

The Tonto National Forest was created at the request of irrigators in the Salt River Valley and the Reclamation Service to protect the watershed above the Salt River Valley.

Farmers in the Salt River Valley were faced with severe water supply problems in the late 1880s and early 1900s due to drought conditions. During drought years, there was insufficient water to meet all their needs. At other times when the rains did come, they resulted in raging torrents that swept down the river channels and destroyed the diversion structures for the irrigation canals (Marcus 1983). The reduced supply of water available during the severe drought of the 1890s and early 1900s was attributed to denudation of forest lands by timber operations and overgrazing, as well as to climatic circumstances (Holsinger 1904 in Marcus 1983). The farmers of the Salt River Valley expressed interest in the creation of forest reserves for prolonging snow cover and providing a more dependable year-round water supply.

The Reclamation Service was concerned with preventing erosion and siltation which could profoundly impact reservoir projects (Marcus 1983). Reclamation was concerned about the effect of overgrazing on watershed condition and the potential to exacerbate erosion and siltation of reservoirs. Reclamation lobbied for the inclusion of millions of acres of key western watersheds in the forest reserve system because they knew the Forest Service had the authority to prevent overgrazing on National Forest System lands (Marcus 1983).

A report prepared in 1905 recommended creating the Tonto Forest Reserve for the protection of timber and watershed (Cohoon and Holsinger 1905 cited in Marcus 1983). The report identified that the U.S. Reclamation Service believed establishment of the forest reserve was essential for the success of the Tonto Dam Project (Roosevelt Dam) and that Salt River Valley water users were also unanimously in favor of the Reserve (Marcus 1983). Acting on this report, President Theodore Roosevelt created the Tonto Forest Reserve on October 3, 1905. The original proclamation included 1,115,000 acres located below the Mogollon Rim and above 4,000 feet elevation. At the time of reservation, the condition of the Salt and Verde River watershed, already stressed from drought, was rapidly deteriorating due to overgrazing (Cohoon 1904, Holsinger 1904, Croxen 1926, cited in Marcus 1983). On January 13, 1908, primarily at the urging of the Reclamation Service, the size of the Tonto Forest Reserve was more than doubled to provide additional watershed protection for lands draining into Roosevelt Lake, for lands along the west side of the Mazatzal Mountains, and for lands draining to a proposed reservoir on Queen Creek (Marcus 1983).

The 2012 Planning Rule

Implementation of the 2012 Planning Rule requires preparation of an assessment that, in terms of water resources, “should identify and evaluate available information for watersheds and water resources (surface and groundwater) and their role in sustaining the structure and function of terrestrial, riparian, and aquatic ecosystems within the plan area and beyond the plan area where relevant to the plan” (Forest Service Handbook 1909.12, chapter 10, section 12.23).

The purpose of this analysis is to evaluate water resource characteristics that are most important for development of plan components. This analysis includes an evaluation of current and historic (where possible) water resources, disturbances and processes, trends and projected future conditions, and an evaluation of ecosystem risks with the objective of identifying specific ecological need for changes in the forest plan.

Water resource characteristics important for sustaining the structure and function of ecosystems and for identifying need for changes in the forest plan are displayed in table 62.

Table 62. Water resource features and key ecosystem characteristics assessed

Water Resource Feature	Ecosystem Characteristic
Watersheds	Extent Condition
Streams	Extent Condition Water quantity
Springs and Seeps	Number Development
Stock tanks	Number
Water Yield	Precipitation Stream Flow Groundwater Recharge/Discharge Water Uses and Demands
Water quality	Assessment of conditions on Tonto National Forest
Water rights	Numbers Location

Data

Data used for analysis of water features such as streams, springs, and riparian areas are from the Tonto National Forest GIS datasets, including National Hydrography Data from the U.S. Geological Survey, water quality data from the Arizona Department of Environmental Quality, water rights data from the Arizona Department of Water Resources, and on-site data collected by the Tonto National Forest personnel. Additional data were used as indicated by references throughout this report.

To assess the miles of perennial streams both in the boundaries of the Tonto National Forest and the context area beyond those boundaries, it was necessary to use data that are less accurate than data available specifically for the Tonto National Forest. Perennial stream miles were estimated using the National Hydrography Dataset. The Arizona Department of Water Resources has updated much of the National Hydrography Dataset information available within the context area and provided the updated information to the Tonto National Forest. The updated dataset was used for the perennial stream analysis. Data developed by the Tonto National Forest from the Arizona Department of Water Resources National Hydrography Dataset GIS layers were used for assessing perennial, intermittent, and ephemeral stream miles within the boundaries of the Tonto National Forest.

Scales of Analysis

This analysis is based on a variety of watershed scales. Watersheds are defined by the extent of the topographic area that drains to a single point in a stream or river system. Watersheds are cataloged using a uniform hierarchical system developed by the U.S. Geological Survey. The United States is divided and subdivided into successively smaller hydrologic units, or watersheds.

The hydrologic units are nested within each other and range from the largest (regions) to the smallest (subwatersheds). Each hydrologic unit is identified by a unique hydrologic unit code consisting of 2 to 12 digits that are based on six levels of classification in the hydrologic unit system. Table 63 displays an example of the hierarchical labeling of a 12-digit hydrologic unit codes subwatershed on the Tonto National Forest.

Table 63. Hydrologic unit code terms and examples

Hierarchy Term	Hydrologic Unit Level	Hydrologic Unit Code Number	Tonto National Forest Example
Region	1st-level hydrologic unit	15	Lower Colorado
Subregion	2nd-level hydrologic unit	1506	Salt River
Basin	3rd-level hydrologic unit	150602	Verde
Subbasin	4th-level hydrologic unit	15060203	Lower Verde
Watershed	5th-level hydrologic unit	1506020306	Sycamore Creek
Subwatershed	6th-level hydrologic unit	150602030601	Upper Sycamore Creek

The Tonto National Forest lies entirely within the Lower Colorado River Region, within parts of four subregions (Upper Gila, Middle Gila, Salt, and Lower Gila), within parts of five basins (Upper Gila, Middle Gila, Salt, Verde, and Lower Gila-Agua Fria) and within portions of seven subbasins.

The analysis uses subbasins for the broadest scale of assessment and subwatersheds for the finest scale. Fourth-level (subbasin-level) and 5th-level (watershed-level) hydrologic unit codes are used for the context area assessment and 5th- and 6th-level (subwatershed-level) hydrologic unit codes are used for the assessment at the planning unit scale (within the Tonto National Forest boundary). There are 35 fifth-level watersheds that range in size from 100 to 400 square miles and 197 fourth-level subwatersheds ranging in size from 10,000 to 50,000 acres that lie partly or entirely within the Tonto National Forest.

Watershed Extent and Perennial Streams

This section describes the 4th-, 5th-, and 6th-level watersheds that lie within or partly within the Tonto National Forest. It also describes the extent of perennial stream miles in these watersheds. The figures below display 4th-level subbasins and 5th-level watersheds.

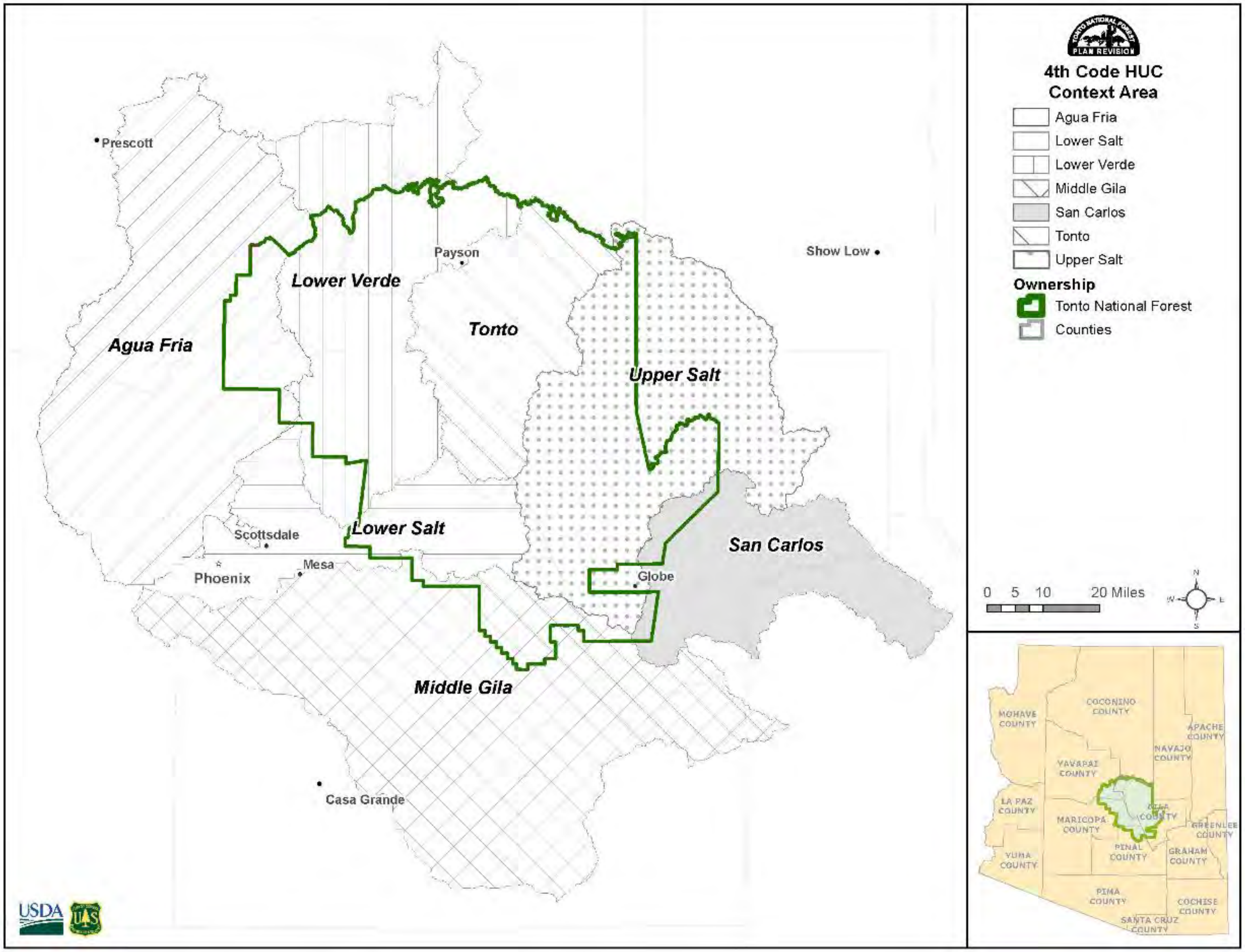


Figure 29. Fourth-level hydrologic unit subbasins in the context area

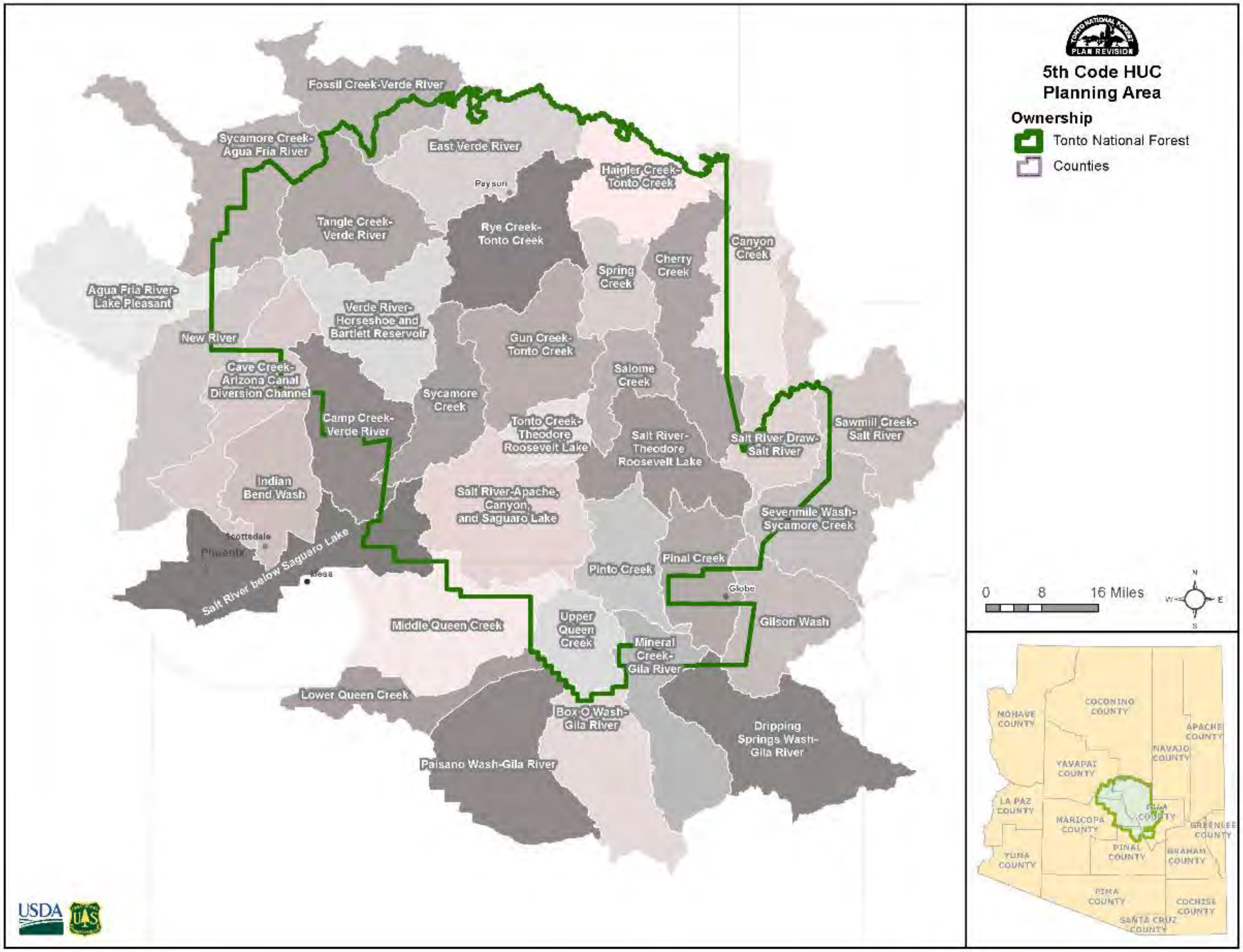


Figure 30. Fifth-level hydrologic unit watersheds within the planning area

Setting above Planning Unit

Table 64 displays watershed extent and perennial stream miles by 4th-level subbasin for the entire subbasin and for the portion within the Tonto National Forest. Table 65 displays the same information for 5th-level watersheds.

Table 64. Subbasin and perennial stream extent on the Tonto National Forest (NF)

Subbasin Name	Subbasin Code	Subbasin Area (square miles)	Tonto NF Area (square miles)	Percent Tonto NF Area	Perennial Stream Miles in the Subbasin	Perennial Stream Miles in the Tonto NF	Tonto NF Stream Miles as a percent of the Subbasin
San Carlos	15040007	1,075	98	9.1%	36.1	0	0.0%
Middle Gila	15050100	3,326	260	7.8%	94.2	2.2	2.3%
Upper Salt	15060103	2,152	1,197	55.6%	265.6	125.1	47.1%
Tonto	15060105	1,048	1,038	99.0%	119.6	119.6	100.0%
Lower Salt	15060106	997	457	45.9%	22.4	14	62.5%
Lower Verde	15060203	1,965	1,297	66.0%	284.7	184	64.6%
Agua Fria	15070102	2,766	286	10.4%	44.7	3	6.7%
Totals	NA	13,330	4,634	34.8%	867.3	447.9	51.6%

Notes: NA = not applicable; Perennial stream miles do not include stream miles through reservoirs or lakes.

Subbasins

Portions of seven subbasins lie partly in the Tonto National Forest. The majority (99 percent) of the Tonto subbasin lies within the Tonto National Forest boundaries. The Tonto National Forest is clearly a major contributor to the ecological sustainability of this watershed. It also contains substantial portions of the Upper Salt River (56 percent), Lower Salt River (46 percent), and Lower Verde River (66 percent) subbasins. Although the portion of these watersheds lying within the Tonto National Forest suggests the Tonto is a significant contributor to the ecological sustainability of these systems, most of the portion of the Upper Salt and Lower Verde subbasins outside the national forest is upstream from the Tonto, which reduces its contribution to the ecological sustainability of the non-forest portions of these subbasins. Subbasin contributions from the Tonto portion of the Lower Salt subbasin to ecological sustainability of the subbasin as a whole are reduced by reservoirs on the Salt River within the Tonto National Forest and the highly developed character of much of the other land ownerships in the subbasin (Phoenix metropolitan area). The Tonto National Forest provides 10 percent or less of the watershed area for the remaining three subbasins (San Carlos, Middle Gila, and Agua Fria), suggesting that at the broad scale, it is not a significant contributor to the sustainability of these systems.

Perennial Streams by Subbasin

The National Hydrography Dataset updated by the Arizona Department of Water Resources identifies 448 miles of perennial streams within the Tonto National Forest and 867 miles within the seven subbasins that intersect the national forest. Major perennial streams on the Tonto include the Salt and Verde Rivers, the East Verde River, and Tonto Creek. Fossil Creek (which forms part of the boundary between the Coconino and Tonto National Forests), and a 41-mile reach of the Verde River extending from Beasley Flat near Camp Verde to the confluence with Red Creek above Horseshoe Lake, are the only currently designated Wild and Scenic Rivers in

Arizona. On an overall basis, the Tonto National Forest occupies 35 percent of the area within the seven subbasins that form the context area for the Tonto National Forest planning unit, yet contains about 52 percent of the perennial stream miles in the subbasins. Perennial streams in the context area are displayed in figure 31.

The San Carlos subbasin supports approximately 36 miles of perennial streams. The Tonto National Forest occupies less than 10 percent of the subbasin and supports no perennial streams within its portion of the subbasin. The Tonto also supports only small percentages of perennial streams on the Middle Gila (2.3 percent), and Agua Fria (6.7 percent) subbasins where the national forest again comprises small percentages of the subbasins (7.8 percent and 10.4 percent respectively). The percent of perennial stream miles on the Tonto National Forest in each of these subbasins is less than the percent of the subbasin on the national forest. Much of the perennial stream mileage in the Middle Gila subbasin occurs in the Gila River. Stream flow in the Gila River is controlled by releases from San Carlos Reservoir. The contribution of the Tonto National Forest to overall ecological sustainability of aquatic resources in these subbasins is small.

The Lower Salt subbasin drains the watershed area, excluding the Verde River, from Roosevelt Lake to the confluence with the Gila River. The Tonto National Forest occupies slightly less than 50 percent of this subbasin but contains 62 percent of the perennial streams. The Salt River flows through this subbasin and provides most of the perennial stream miles within the national forest portion of the subbasin. All of the perennial flow on the Tonto is controlled by reservoir releases from four reservoirs that provide water for water users in the Salt River Valley, including the Phoenix metropolitan area. The Granite Reef Diversion Dam at the western boundary of the Tonto National Forest diverts flow in the Salt River into canals that distribute water to Salt River Valley users. The Salt River becomes intermittent to ephemeral below the dam until it reaches areas where treated effluent is discharged to the river in the Phoenix Metropolitan area.

The Upper Salt and Tonto subbasins drain most of the eastern side of the Tonto National Forest and join at Roosevelt Lake. Almost the entire Tonto subbasin lies within the national forest boundary. The percent of perennial stream miles within the national forest portion of these subbasins (47 percent and 100 percent respectively) is proportional to the percent of subbasin area (56 percent and 99 percent respectively) within the Tonto National Forest. The Lower Verde subbasin drains the watershed area extending from Camp Verde in the north to the confluence with the Salt River in the south, approximately 3 miles east of the Granite Reef Diversion Dam. The percent of the perennial stream miles (65 percent) within the national forest portion of the subbasin is proportional to the percent of the subbasin area (66 percent) within the Tonto National Forest.

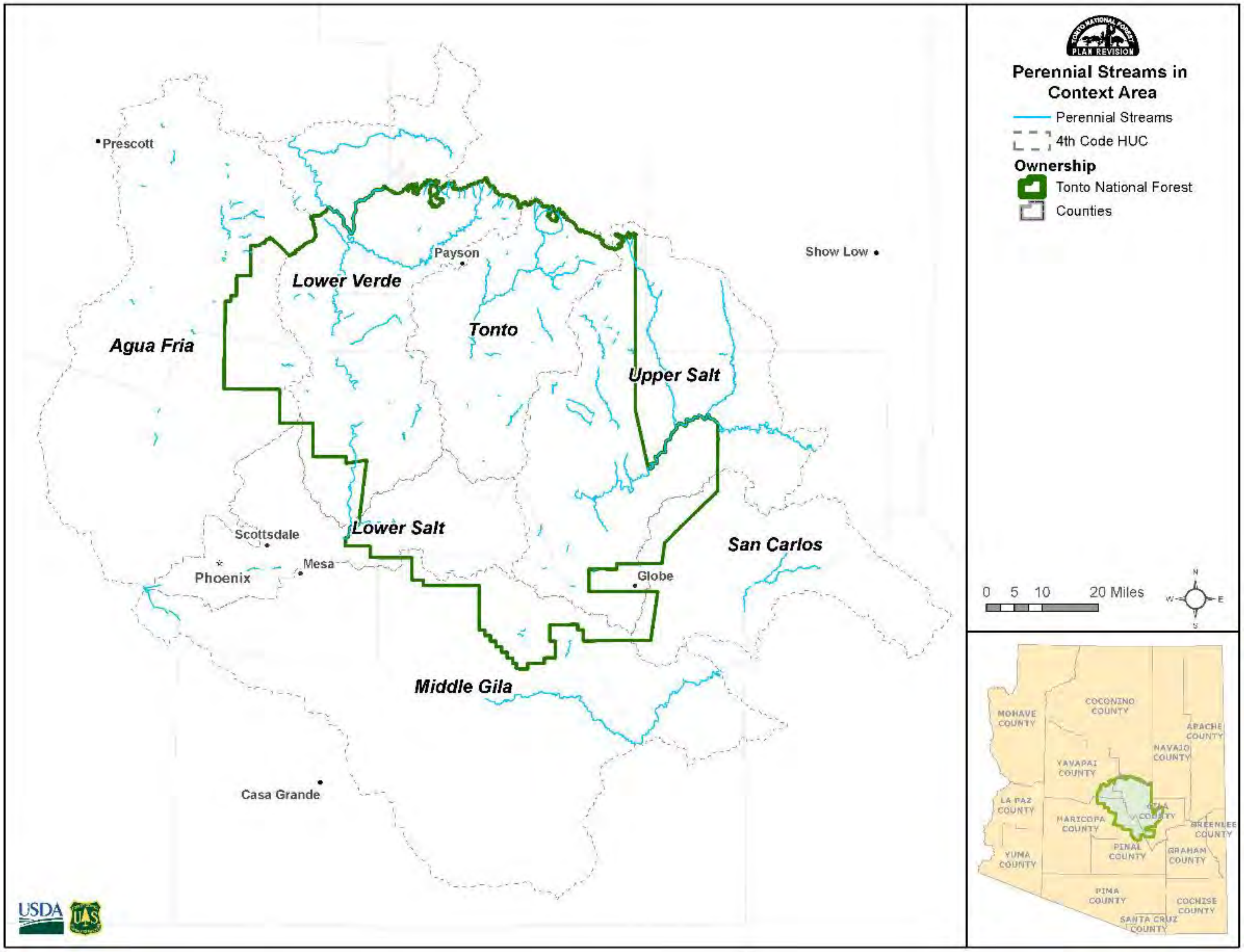


Figure 31. Perennial streams located in the context area

Key Findings

On an overall basis, the Tonto National Forest provides only 35 percent of the watershed area of the subbasins lying partly within the national forest boundary but contains 52 percent of the perennial stream miles within these watersheds. The Tonto National Forest occupies a mountainous area that forms the headwaters for a number of perennial streams. Higher than normal rainfall and runoff from these areas contributes to the higher percentage of perennial stream miles within the Tonto National Forest portion of the subbasins. The Tonto contribution to maintaining favorable conditions of flow (quantity, quality, timing and magnitude of stream flows) at the subbasin scale is important for supporting ecological sustainability within the portions of the national forest that are not affected by dams and reservoirs (dams and reservoirs occur in the lower portions of the Salt and Verde Rivers). The contribution of perennial flows from the Tonto National Forest to portions of the subbasins outside the national forest boundary is small because the portions of these subbasins are either up-gradient from the Tonto; affected by dams, reservoirs, and development; or contain only a small percentage of National Forest System lands in the subbasin area.

Setting At and Below Planning Unit

The watershed and perennial stream setting at the planning unit is based on watersheds (5^{th}-level hydrologic units). The setting below the planning unit is based on subwatersheds (6^{th}-level hydrologic units). Figure 32 through figure 39 display 6^{th}-level subwatersheds in and intersecting the Tonto National Forest, and figure 40 displays the location of perennial streams in the subwatersheds. Table 65 identifies watershed extent and perennial stream miles by watershed in and outside the Tonto National Forest boundary.

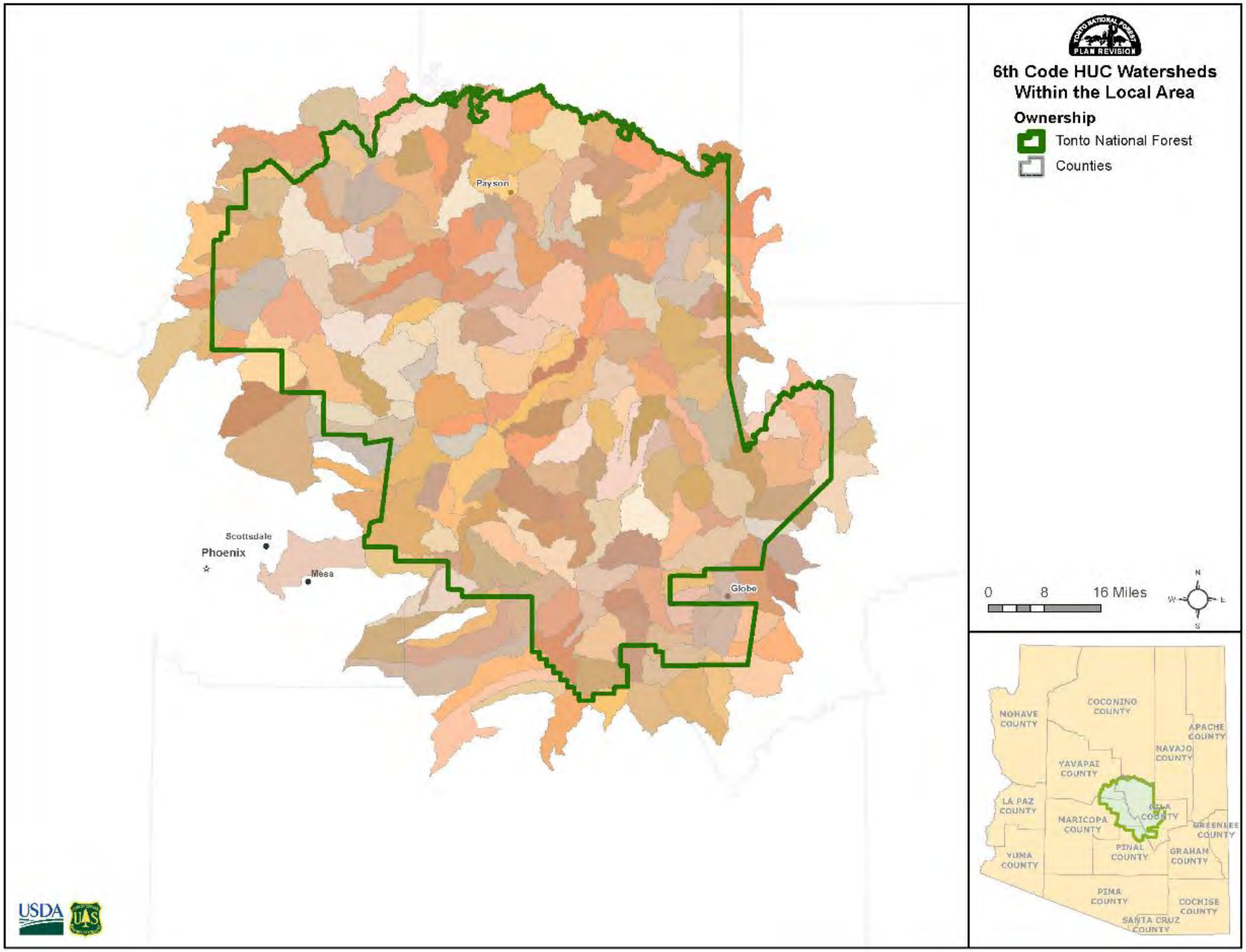


Figure 32. Sixth-level subwatersheds in the local area

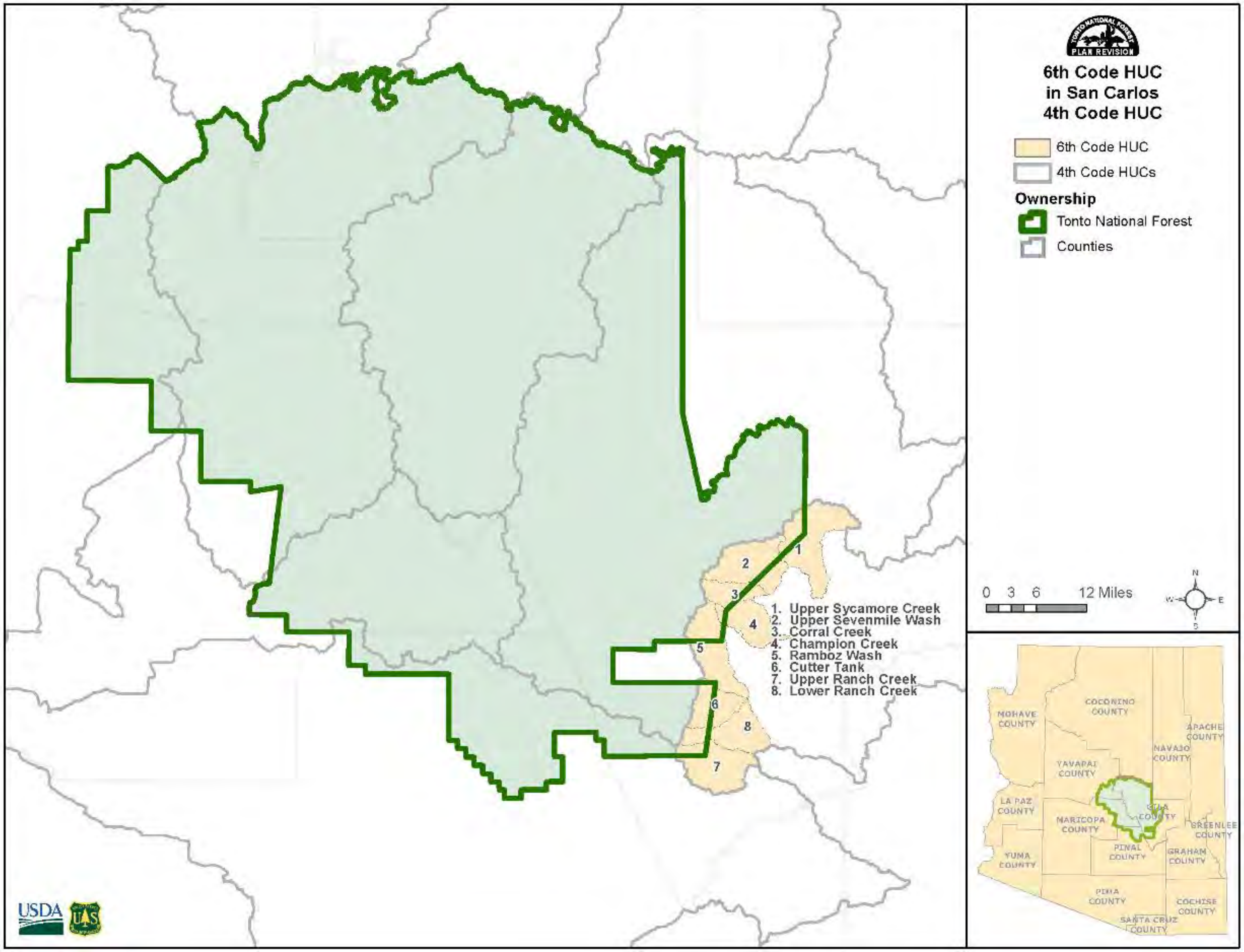


Figure 33. Sixth-level subwatersheds in the San Carlos subbasin

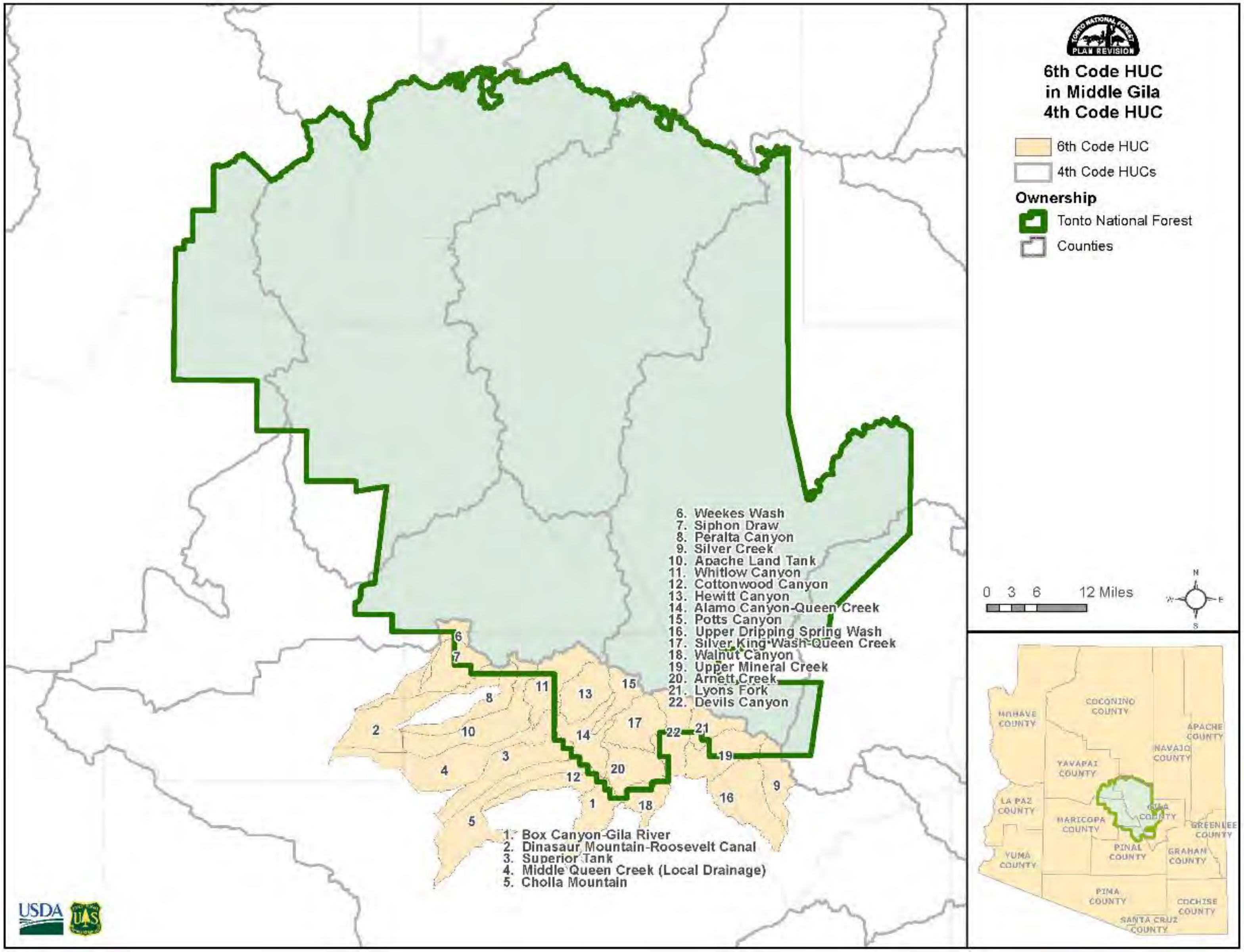


Figure 34. Sixth-level subwatersheds in the Middle Gila subbasin

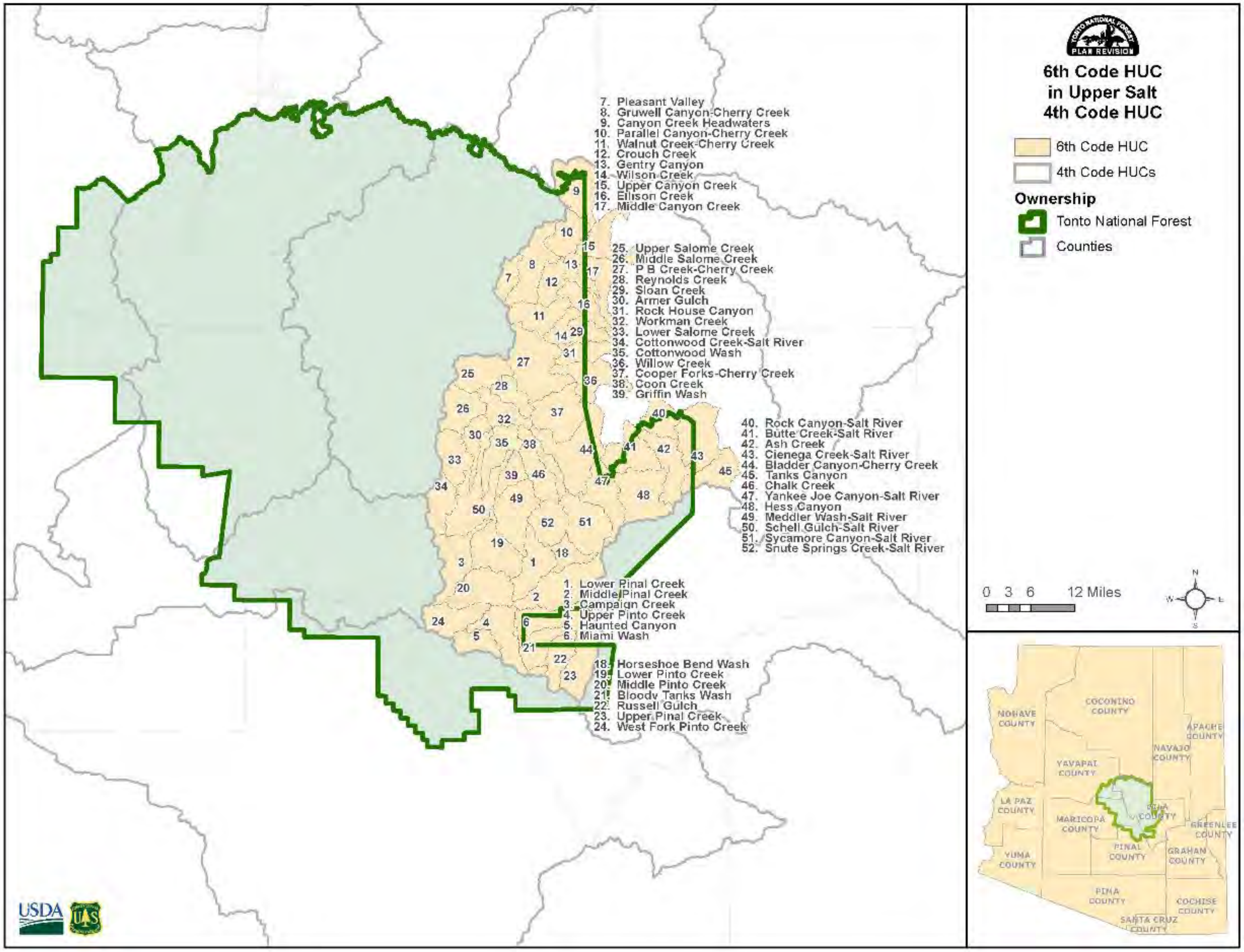


Figure 35. Sixth-level subwatersheds in the Upper Salt subbasin

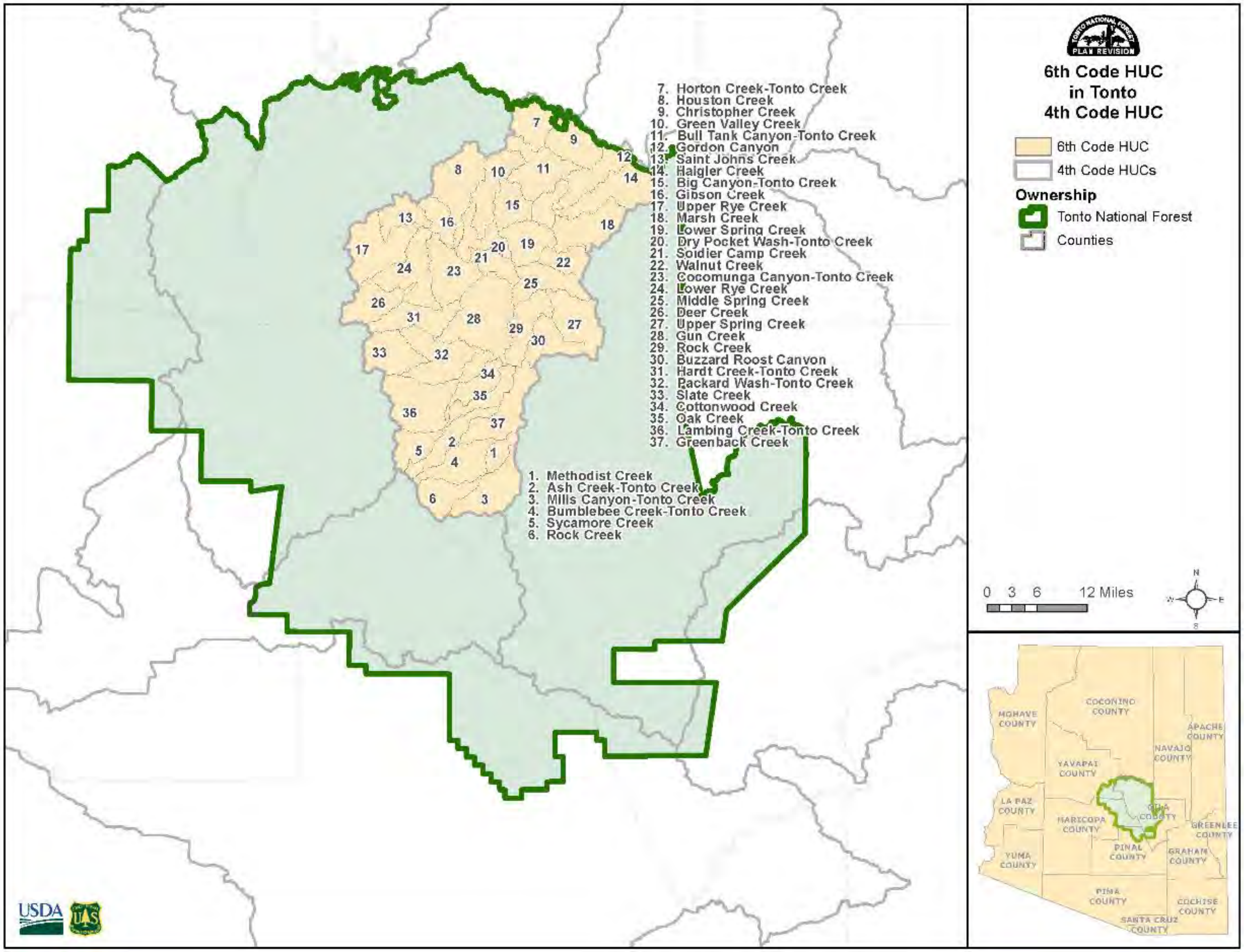


Figure 36. Sixth-level subwatersheds in the Tonto subbasin

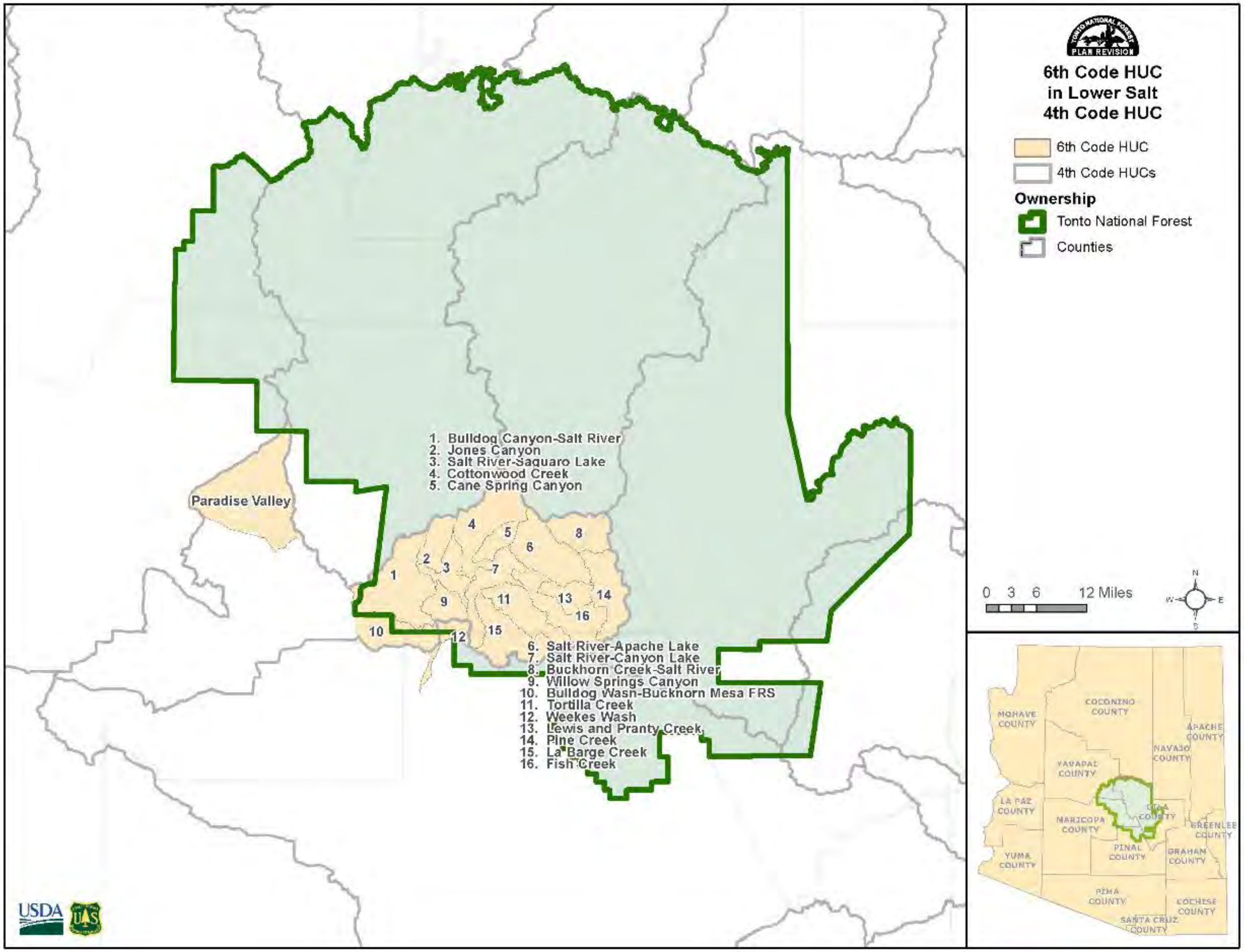


Figure 37. Sixth-level subwatersheds in the Lower Salt subbasin

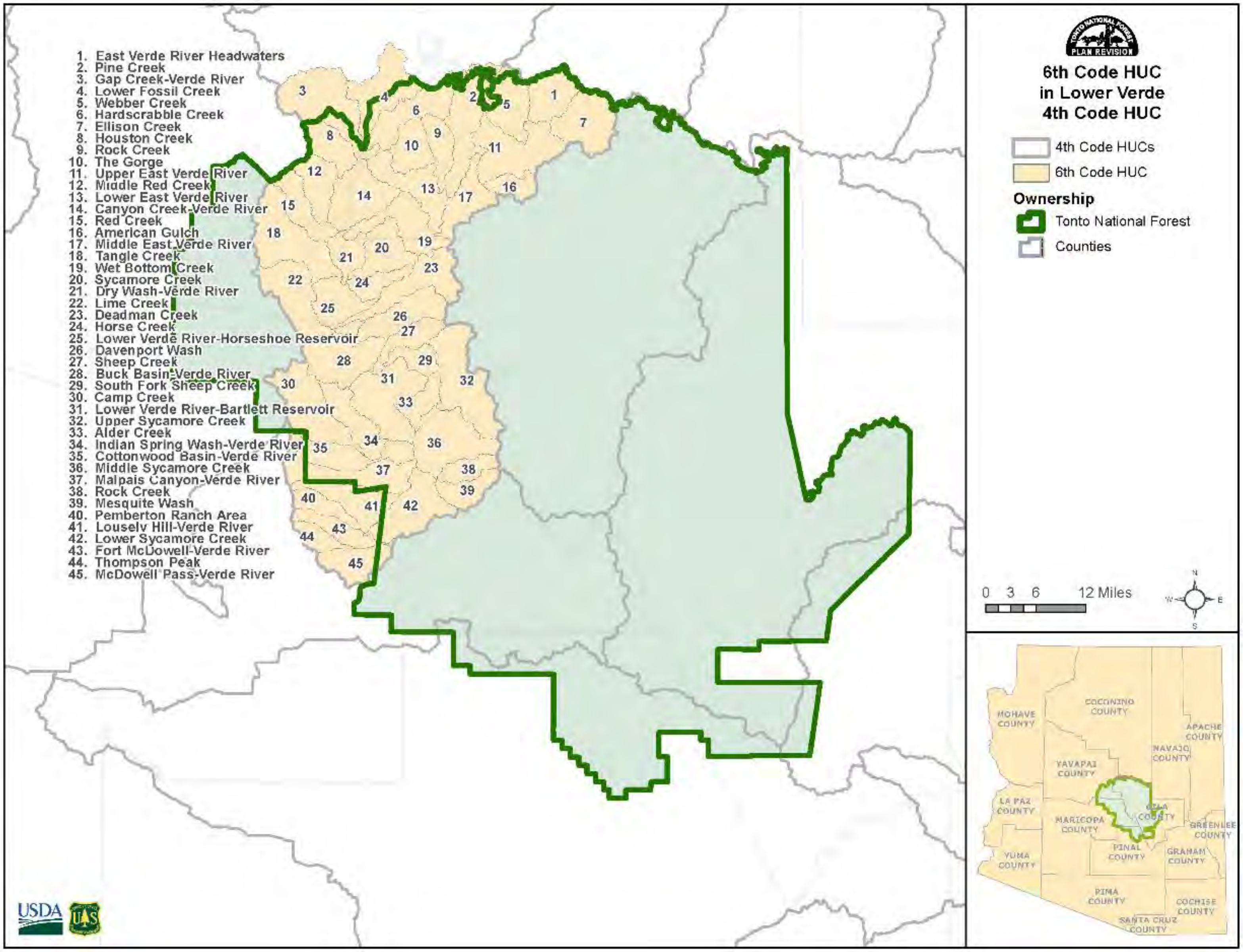


Figure 38. Sixth-level subwatersheds in the Lower Verde subbasin

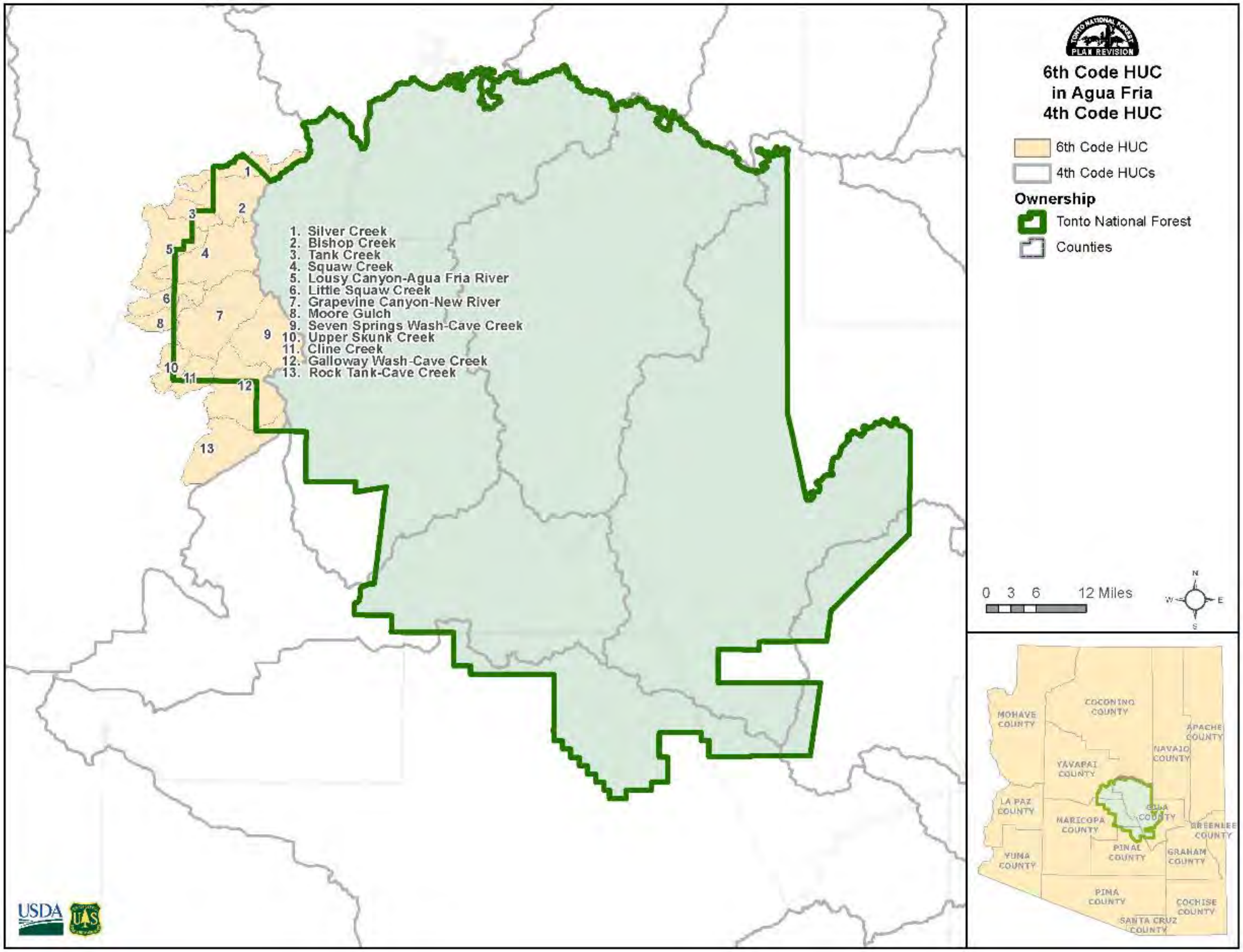


Figure 39. Sixth-level subwatersheds in the Agua Fria subbasin

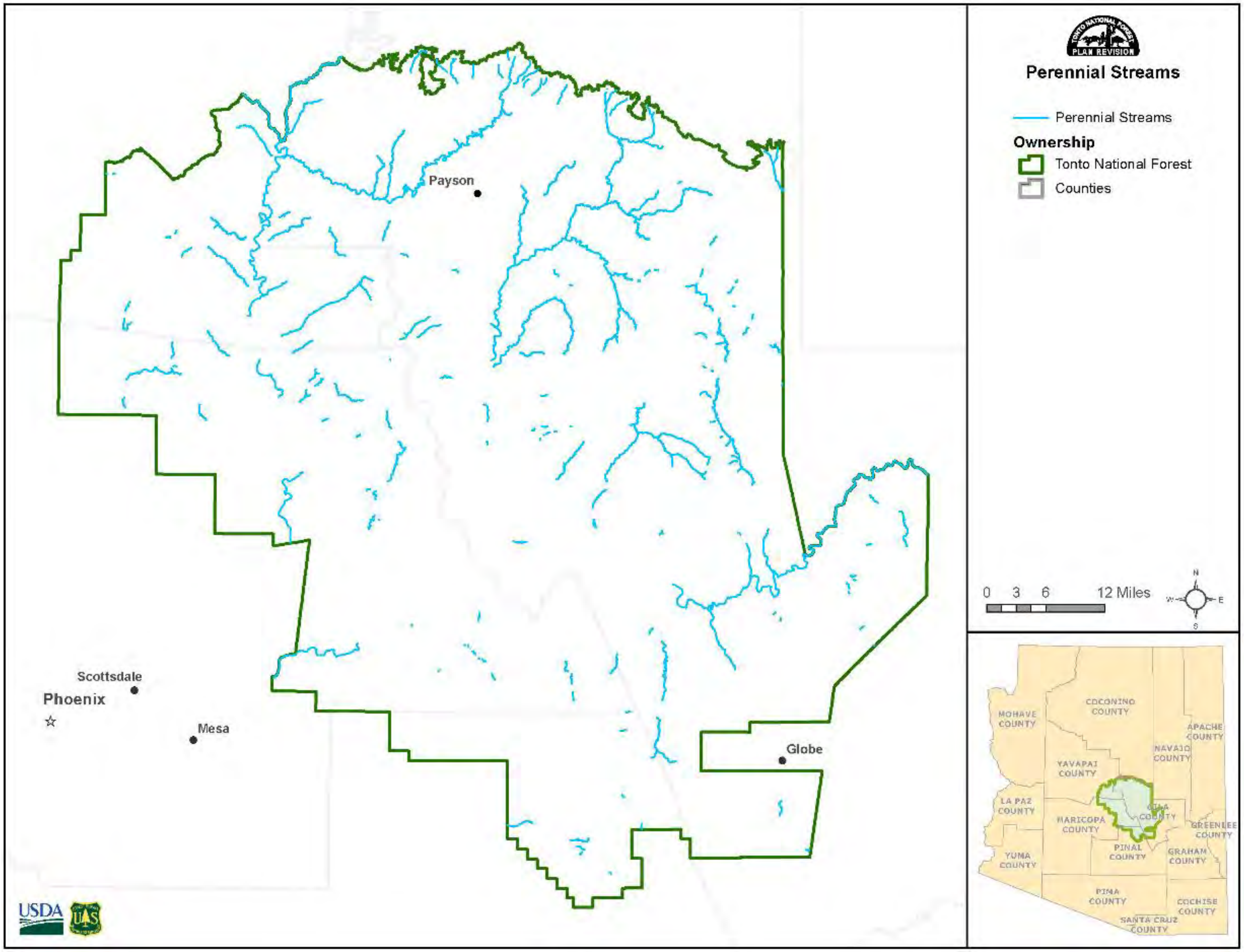


Figure 40. Perennial streams at the plan area scale

Table 65 presents data for each subbasin's watershed area and perennial stream miles. Some watersheds do not support any perennial streams. Where this condition exists, the miles of perennial streams in both the watershed and the Tonto National Forest are represented by "0"

Table 65. Watershed and perennial stream extent for each subbasin within and surrounding the Tonto National Forest (NF)

Watersheds in Subbasins	Watershed Number	Watershed Area (square miles)	Tonto NF Watershed Area (square miles)	Watershed Percent of Tonto NF	Miles Perennial Streams in Watershed	Miles Perennial Streams in Tonto NF	Percent of Watershed with Perennial Streams in Tonto NF
San Carlos Subbasin							
Sevenmile Wash-Sycamore Creek	1504000702	253	58	23.1%	0.00	0.00	0.0%
Gilson Wash	1504000703	245	40	16.2%	0.00	0.00	0.0%
Middle Gila Subbasin							
Dripping Springs Wash-Gila River	1505010001	393	5	1.3%	33.10	0.00	0.0%
Mineral Creek-Gila River	1505010002	259	55	21.3%	25.16	0.00	0.0%
Box O Wash-Gila River	1505010003	298	4	1.5%	21.80	0.00	0.0%
Upper Queen Creek	1505010004	143	143	99.4%	2.19	2.19	100.0%
Paisano Wash-Gila River	1505010007	374	2	0.4%	0.00	0.00	0.0%
Middle Queen Creek	1505010008	381	49	12.9%	0.00	0.00	0.0%
Lower Queen Creek	1505010009	157	2	1.3%	0.00	0.00	0.0%
Upper Salt Subbasin							
Sawmill Creek-Salt River	1506010302	267	17	6.2%	40.78	0.92	2.3%
Canyon Creek	1506010303	318	66	20.6%	57.83	9.82	17.0%
Cherry Creek	1506010304	278	265	95.3%	40.89	40.76	99.7%
Salt River Draw-Salt River	1506010305	236	132	55.8%	30.28	15.88	52.4%
Pinal Creek	1506010306	200	155	77.5%	9.48	7.45	78.6%
Pinto Creek	1506010307	186	186	100%	5.54	5.54	100.0%
Salome Creek	1506010308	119	119	100%	17.44	17.44	100.0%
Salt River-Theodore Roosevelt Lake	1506010309	259	259	100%	27.30	27.30	100.0%

Watersheds in Subbasins	Watershed Number	Watershed Area (square miles)	Tonto NF Watershed Area (square miles)	Watershed Percent of Tonto NF	Miles Perennial Streams in Watershed	Miles Perennial Streams in Tonto NF	Percent of Watershed with Perennial Streams in Tonto NF
Tonto Subbasin							
Spring Creek	1506010501	147	147	100%	8.97	8.97	100.0%
Haigler Creek-Tonto Creek	1506010502	224	214	95.5%	67.39	67.38	100.0%
Rye Creek-Tonto Creek	1506010503	301	301	100%	32.49	32.49	100.0%
Gun Creek-Tonto Creek	1506010504	283	283	100%	10.31	10.31	100.0%
Tonto Creek-Theodore Roosevelt Lake	1506010505	93	93	100%	0.50	0.50	100.0%
Lower Salt Subbasin							
Salt River-Apache, Canyon, and Saguaro Lake	1506010601	388	388	100%	0.00	0.00	0.0%
Indian Bend Wash	1506010602	221	1	0.4%	0.00	0.00	0.0%
Salt River below Saguaro Lake	1506010603	431	68	15.7%	21.90	13.90	63.5%
Lower Verde Subbasin							
East Verde River	1506020302	331	317	95.8%	83.17	82.64	99.4%
Fossil Creek-Verde River	1506020303	299	62	20.8%	52.08	13.14	25.2%
Tangle Creek-Verde River	1506020304	278	278	100%	39.59	39.59	100.0%
Verde River-Horseshoe and Bartlett Reservoir	1506020305	300	300	100%	28.30	28.30	100.0%
Sycamore Creek	1506020306	193	190	98.7%	9.67	9.23	95.5%
Camp Creek-Verde River	1506020307	266	150	56.3%	29.05	11.81	40.7%
Agua Fria Subbasin							
Sycamore Creek-Agua Fria River	1507010204	366	105	28.6%	21.32	0.28	1.3%
Agua Fria River-Lake Pleasant	1507010205	372	11	3.1%	3.65	0.00	0.0%
Cave Creek-Arizona Canal Diversion Channel	1507010206	285	89	31.1%	2.67	2.67	100.0%
New River	1507010208	363	82	22.5%	0.00	0.00	0.0%
Total – All Subbasins							
Total	not applicable	9,507	4,634	48.7%	723	448	62%

Watersheds

Thirty-five watersheds lie partly or entirely in the boundaries of the Tonto National Forest (see figure 32). The percent of watershed area in the Tonto ranges from less than 1 percent for two watersheds to 100 percent of the watershed area of 10 watersheds. Only small percentages of most of the watersheds in the San Carlos, Middle Gila, Agua Fria, and Lower Salt subbasins lie within theTonto National Forest. The Upper Queen Creek watershed in the Middle Gila subbasin and the Salt River-Apache, Canyon, and Saguaro Lake watershed in the Lower Salt subbasin are the only watersheds primarily within the Tonto in these four subbasins. Less than 30 percent of the watershed area of all but one of the other watersheds in these subbasins lies within the Tonto National Forest. In contrast, most of the watersheds in the Tonto, Upper Salt, and Lower Verde subbasins lie primarily in the Tonto. On an overall basis, nearly 50 percent of the area of the 35 watersheds intersecting the Tonto National Forest lies within its boundary. The Tonto National Forest occupies a greater percent of the watersheds than of the larger subbasins (35 percent).

Greater than 90 percent of the area of 15 of the watersheds are within the boundaries of the Tonto National Forest. Watershed processes affecting ecological sustainability on these watersheds are dominated by conditions on the Tonto. From 50 to 90 percent of the area of three of the watersheds lie within the boundaries of the Tonto National Forest. The Tonto contributes substantially to watershed processes affecting ecological sustainability on these watersheds. From 10 to 50 percent of the area of nine of the watersheds are within the Tonto’s boundaries. Conditions on the Tonto are less significant to watershed processes affecting ecological sustainability on these watersheds than on the previous groups of watersheds. The Tonto National Forest provides less than 10 percent of the watershed area for seven of the watersheds. The contribution of the Tonto National Forest to watershed processes affecting ecological sustainability on these watersheds is small.

Perennial Streams by Watershed

There are 723 miles of perennial streams in the 35 watersheds that intersect the Tonto National Forest (see figure 40). Of these streams, 448 miles are located within its boundary. The percent of perennial streams (62 percent) in the national forest is greater than the percent of watershed area (49 percent) in the national forest. Table 66 below displays the contribution of perennial stream miles in the Tonto National Forest to ecological sustainability.

Table 66. Perennial stream miles in the Tonto National Forest (NF)

Percent of Perennial Stream Miles in Tonto NF Boundary	Number of Watersheds in Category	Tonto NF Contribution to Ecological Sustainability
100 percent	12	Entire
80 - 99 percent	3	Primary
50 - 79 percent	3	Significant
20 - 49 percent	2	Less Significant
less than 20 percent	3	Small
Perennial streams absent within the Tonto National Forest	4	Indirect effects only
Perennial streams absent within entire watershed	8	Not Applicable

The entire watershed area of 10 watersheds, where 100 percent of perennial streams are located within the Tonto, are also entirely within the Tonto National Forest boundary.

Subwatersheds

There are 197 subwatersheds that lie partly or entirely within the boundaries of the Tonto National Forest. Of these watersheds, 112 lie entirely within the Tonto's boundaries, while less than 5 percent of the watershed area of 14 subwatersheds are within the boundaries. Overall, 72 percent of the watershed areas of the 197 subwatersheds that intersect the Tonto National Forest lie within the boundary. This compares with the 35 percent of subbasins and 49 percent of watersheds.

Perennial Streams by Subwatershed

Approximately 790 miles of perennial streams lie within 6^{th}-level watersheds that intersect the Tonto National Forest. Almost 700 miles (89 percent) are within the Tonto's boundary. Perennial streams exist in 132 of the subwatersheds that intersect or are contained within the Tonto's boundary. Perennial streams occur entirely within the national forest in 108 of the subwatersheds and entirely outside the boundary within 14 subwatersheds. Perennial streams do not occur within 65 (33 percent) subwatersheds. Table 67 summarizes perennial stream flow data for subwatersheds.

Table 67. Subwatershed perennial stream data

Watershed Information	Number of Watersheds	Percent of Watersheds
Perennial streams are entirely within the Tonto National Forest	108	54.8
From 75-99% of perennial stream length is within the national forest boundary	4	2
From 50-74% of perennial stream length is within the national forest boundary	3	1.5
From 25-49% of perennial stream length is within the national forest boundary	1	0.5
From 0-24% of perennial stream length is within the national forest boundary	2	1
Perennial stream miles are entirely outside the national forest boundary	14	7.1
Perennial streams do not exist with subwatershed	65	33

Key Findings

The Tonto National Forest planning unit occupies about 49 percent of the watersheds intersecting it but supports 62 percent of the perennial streams. Perennial stream flows in these watersheds are more important for supporting ecological sustainability within the Tonto than in the context area outside the Tonto. The majority (86 percent) of the watersheds in the Tonto ultimately drain to the Salt River, which exits the Tonto's boundary at Granite Reef Diversion Dam just east of the Phoenix metropolitan area. At the dam, flow in the Salt River is diverted into canals that deliver water to water users in the Phoenix metropolitan area. These watersheds have little impact on the ecological sustainability of downstream watersheds due to dams and reservoirs within the Tonto that control water discharge off the national forest, and the highly altered characteristics of the urbanized watersheds and channels below the Tonto. Watersheds with the greatest contribution to ecological sustainability downstream from the Tonto are probably those within the Agua Fria subbasin such as Cave Creek and New River (although the Tonto National Forest portion of these watersheds is only 31 percent and 22 percent respectively), which exit the Tonto into minimally disturbed channels until they reach urbanized areas several miles below.

Current and Historical Disturbances

The following section discusses current and historic disturbances that affect water resource conditions within the Tonto National Forest. Historical refers to conditions prior to European settlement and describes reference conditions for comparison with existing conditions. The description of current conditions refers to existing conditions as well as natural and human disturbances and processes since European settlement, which have led to the current situation.

Watershed conditions in the Southwest reflect prehistoric, historic, and current climatic conditions and land use practices. Geologic evidence identifies a sequence of valley filling and erosion that resulted in the development of three terrace levels in most alluvial valleys across the western United States (Leopold 1997). Development of these features began following the last ice age which ended about 10,000 years ago. A cool moist period following the ice age resulted in filling or alluviation of many western valleys. The period of alluviation ended with the Altithermal period which lasted from 8,000 to 5,000 years before present. Conditions during the Altithermal period were drier and warmer than today. Extensive valley erosion is believed to have occurred during this period, resulting in a period of valley downcutting and terrace formation (Leopold 1997). The Altithermal period was followed by a period of relative humidity and valley filling that was ended by a 200 year drought from approximately A.D. 1200 to 1400 (Leopold 1994). Erosion and downcutting of aggraded valley bottom material occurred during this period and resulted in a second sequence of terraces. Humid and cool conditions followed in the period known as the Little Ice Age that ended about 1860. Aggradation and valley filling occurred again during this period. A period of increased aridity followed, and caused widespread erosion of western valleys between 1880 and 1920 (Leopold 1994).

Leopold (1994) believes that the geologic evidence leads to the generalization that valley alluviation or deposition occurs during periods of relative humidity, periods when there are numerous light rainfalls in addition to heavy storms, and that erosion and valley degradation occurs during periods of climatic aridity, when annual precipitation is dominated by sporadic heavy rainfalls and infrequent light rainstorms.

Modern gullies began downcutting in the period 1880 to 1900. The period of historical arroyo downcutting is known to have occurred during a period of unusually large storms that caused extraordinary floods (Webb et al. 2007). Debate about the cause of this downcutting has been ongoing for many years (Webb et al. 2007). Some observers believe overgrazing was responsible while others feel that climatic conditions, combined with livestock grazing, induced arroyo downcutting.

Although livestock were originally introduced to Arizona in the 1700s, large-scale grazing began in the early 1880s. Channel downcutting began in the mid 1880s. A severe drought occurred from 1891 to 1904. This drought, combined with overgrazing, depleted the range so heavily that reportedly half of the livestock died in much of the region. The poor range conditions became associated with arroyo downcutting (Webb et al. 2007).

Early proponents of climate-induced downcutting believed drought, combined with grazing, caused watershed conditions to deteriorate to the extent that runoff was increased (Webb et al. 2007). Other human induced factors may also have contributed to arroyo downcutting. These include irrigation canals and roads, instream gravel mining, irrigation dams, and beaver trapping (Webb et al. 2007).

Beaver trapping in the early 19th century decimated beaver populations. Beaver dams serve as local base level controls. Removal of the beaver and subsequent failure of their dams would have allowed floods to more readily cause downcutting of stream channels.

The period of channel downcutting was followed by a period of channel widening that ceased regionally by the mid 1940s because of decreases in the sizes of floods. Low floodplains were deposited during this period representing the start of arroyo filling (Webb et al. 2007, Leopold 1994). Flooding resumed in central and southern Arizona from 1977 through 1995 causing removal of low terraces along many rivers in the southern part of the region (Webb et al. 2007). Stream systems on the Tonto National Forest were affected by flooding during this period as well. Erosion and reworking of fluvial surfaces occurred on many of the streams within the Tonto.

During periods of valley degradation, downcutting of stream channels would have drained the local alluvial aquifer and induced further destabilization of stream channels by causing dieback or death of the woody riparian vegetation that is dependent on the aquifer. Loss of bank stabilizing riparian vegetation results in bank collapse and widening of newly lowered stream channels (Webb et al. 2007). Stability is reestablished once the channel widens sufficiently to allow development of new floodplain and channel features at the lowered channel bed elevation. Reestablishment of stability in this sequence occurs only in the presence of “good” riparian conditions, where riparian vegetation provides the necessary resistance to flow forces (Rosgen 1996).

Disturbance Mechanisms

Little information is available to document historic range of variation and extent of perennial streams other than from anecdotal information and by inferring past conditions based on knowledge of current conditions. As an alternative approach this analysis will identify general ecological conditions needed to sustain perennial stream extent and related ecosystem diversity.

Mining

Current Disturbances

Mining activities began in the 1870s and 80s with development of silver and copper mines in the Globe-Miami and Superior areas. Mining continues in these areas today and is expected to continue into the future with the discovery of a large copper ore body near Superior by the Resolution Copper Company. Major mines currently operating within the exterior boundaries of the Tonto include the Pinto Valley Mine, which produces copper and molybdenum west of the Globe/Miami area; the Carlota Copper Mine adjacent to the Pinto Valley Mine, which has ceased active mining but continues to leach copper from its leach pad; and Freeport-McMoRan’s Miami Mine, which produces copper. Smaller scale mining of other minerals including gold, tungsten, uranium, lead, gypsum, uranium, mercury, zinc, and asbestos has also occurred on the Tonto National Forest.

Mining disturbances to water resources include erosion of sediment and pollutants from waste rock and tailings piles, pollutant discharge from abandoned mine shafts and adits, contamination of groundwater quality by seepage through tailings, waste rock, leach pads, and underground tunnels and shafts. Mining can also impact water resources by direct impacts on stream channels (from dredging, diversion, and spills); by impoundments to retain sediment and storm water runoff; by groundwater pumping, which affects aquifer storage, discharge from springs and seeps, and base flows in streams; and by the infrastructure necessary to support mine operations such as roads, pipelines, and powerlines.

Periodic spills of tailings have occurred in Pinto Creek (1993, 1997, and 2012). Mining operations in the Pinal Creek Watershed have caused groundwater contamination in Pinal Creek. Contaminated areas in Pinal Creek were designated as a Water Quality Assistance Revolving Fund site and a consortium of mining companies are currently intercepting and treating contaminated groundwater for use in their operations and for discharge back to Pinal Creek. Water quality conditions in the perennial reach of Pinal Creek have improved since treatment began and the creek is now listed as Category 2 (attaining some uses) in the 2012/14 Water Quality Assessment Report (ADEQ 2014). The Tonto National Forest has cleaned up a number of closed mining sites through Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; also known as Superfund) actions and through Burned Area Emergency Response actions. These include mercury mining and milling sites in the upper Sycamore and Slate Creek watersheds, abandoned uranium mines and tailings deposits in the Workman Creek watershed, abandoned asbestos mines in the area of the Tonto north of Globe, and gold mining sites in the Cave Creek, Sycamore Creek, and Tonto Creek watersheds. The Gibson Mine, an abandoned copper mine southeast of Top of the World, was partially cleaned up with Water Quality Assistance Revolving Funds and contributions by the Carlota Copper Company. Discharge from audits and erosion of waste rock piles continues in parts of the Tonto National Forest, most notably in the headwaters of Pinto Creek and sites along the south side of the Pinal Mountains. A CERCLA action is currently in progress for abandoned mine sites in the headwaters of Pinto Creek.

Historical Disturbances

Mining did not occur prior to European settlement.

Roads

Current Disturbances

More than 6,000 miles of motorized routes currently exist within the Tonto National Forest boundary. Road density within the Tonto National Forest currently averages about 1.3 miles per square mile. This density corresponds to a “fair” rating in the Watershed Condition Classification Technical Guide (Potyondy and Geier 2011). The results of the watershed condition classification rating process for the Tonto are discussed in the “Watershed Condition” section of this report.

Roads directly affect natural sediment and hydrologic regimes by altering stream flow, sediment loading, sediment transport and deposition, channel morphology, channel stability, substrate composition, stream temperatures, water quality, and riparian conditions in a watershed (Gucinsky et al. 2001). Roads have three primary effects on hydrologic processes. They intercept rainfall directly on the road surface and road cut-and-fill slopes and intercept subsurface water moving down the hillslope, they concentrate flow either on the surface or in an adjacent ditch or channel, and they divert or reroute water from natural flow paths (Gucinsky et al. 2001; USDA Forest Service 1999).

Roads contribute more sediment to streams than any other land management activity (Gucinsky et al. 2001). Large increases in the amount of sediment delivered to the stream channel can greatly impair or even eliminate fish and aquatic invertebrate habitat and alter the structure and width of streambanks and adjacent riparian zone (Macdonald 1991). The amount of sediment can affect channel shape, sinuosity, and relative balance between pools and riffles. Indirect effects of increased sediment loads may include increased stream temperatures and decreased intergravel dissolved oxygen (Macdonald 1991).

Historical Disturbances

Roads were not constructed prior to European settlement.

Herbivory

Current Disturbances

Although livestock (sheep and cattle) were originally introduced to Arizona in the 1700s, large-scale grazing began in the early 1880s. Livestock grazing has occurred throughout the Tonto National Forest since that time. There are 103 livestock grazing allotments on the national forest that occupy approximately 2.9 million acres. Twelve of these allotments, occupying approximately 463,000 acres, are closed or currently vacant. Two additional areas, the Three Bar Wildlife Area and the Sierra Ancha Experimental Forest, which together occupy about 40,000 acres, are also closed to grazing. Miscellaneous research natural areas and recreation sites are also closed to grazing. Approximately 20 percent of the Tonto National Forest is not currently grazed by livestock. Elk graze in much of the higher elevation portions of the Tonto, particularly in the Payson and Pleasant Valley Ranger Districts.

Livestock and elk grazing in uplands can reduce vegetative ground cover and compact soils. These impacts can increase runoff and erosion and result in increased delivery of sediment to connected streams. A severe drought occurred in Arizona from 1891 to 1904. This drought, combined with overgrazing, depleted the range so heavily that reportedly half of the livestock died in much of the region (Webb et al. 2007). The poor range conditions became associated with stream channel downcutting. Other human-induced factors may also have contributed to arroyo downcutting. These include irrigation canals and roads, instream gravel mining, irrigation dams, and beaver trapping (Webb et al. 2007).

Due to limited distribution of water sources on Tonto and the presence of palatable riparian vegetation, shade, and water along streams, seeps, and springs, livestock often congregate in these areas during the hot summer months. Excessive or poorly timed grazing in riparian areas can damage vegetation, stream channels, and water quality. Existing condition of riparian areas is described in the “Riparian” section of this assessment.

Historical Disturbances

Available information suggests domestic livestock grazing did not occur prior to the arrival of Europeans and could not have had a disturbance effect. Native wildlife species, such as mule and white tail deer, bighorn sheep, antelope, and a native species of elk, were present in portions of the Tonto National Forest. Their effect on water resources is not known. Grazing of riparian areas by elk has impacts similar to those by livestock.

Dams and Impoundments

Current Disturbances

Dams and impoundments impact natural watershed processes by capturing water and sediment that would otherwise move through the river system. Six major reservoirs exist on the Tonto National Forest. These include four reservoirs on the Salt River and two on the Verde River. Table 68, table 69, and table 70 displays the storage capacity and surface area of these reservoirs.

Table 68. Reservoirs on the Salt River within the Tonto National Forest

Dam Name	Reservoir Name	Completion Date	Storage (acre-feet)	Surface Area (acres)
Roosevelt	Theodore Roosevelt Lake	1911	1,653,043	21,493
Horse Mesa	Apache Lake	1927	245,138	2,656
Mormon Flat	Canyon Lake	1925	57,852	950
Stewart Mountain	Saguaro Lake	1930	69,765	1,264

Table 69. Reservoirs on the Verde River within the Tonto National Forest

Dam Name	Reservoir Name	Completion Date	Storage (acre-feet)	Surface Area (acres)
Horseshoe	Horseshoe Reservoir	1946	109,217	2,722
Bartlett	Bartlett Reservoir	1939	178,186	2,815

Table 70. Salt River and Verde River System reservoir totals on the Tonto National Forest

River System Reservoirs	Storage (acre-feet)	Surface Area (acres)
Salt River System	2,025,798	26,363
Verde River System	287,403	5,537
Totals	2,313,201	31,900

The timing and magnitude of flows in the Salt River below the reservoirs is substantially different from those that would occur under natural conditions due to the operating rules for the reservoirs. The majority of the releases from these reservoirs occur in the summer when water is used to generate power for the Phoenix metropolitan area and to provide water for users in the Salt River Valley. Figure 41 displays average monthly discharge at two sites on the Salt River. The first site (USGS gage: Salt River near Roosevelt) is upstream of the reservoirs on the Salt River and displays a natural stream flow hydrograph for the period from 1913 to 2014. The second site (USGS gage: Salt River below Stewart Mountain Dam) is below the four reservoirs on the Salt River and displays mean monthly stream flows resulting from controlled releases from these reservoirs for the period 1940 to 2014. Under natural flow conditions, the highest flows occur in the winter and spring and the lowest flows occur in the summer and fall. The controlled releases from the Salt River reservoirs result in high flows in the spring and summer and low flows in the fall and winter. The difference in flow characteristics between the sites reduces the ecological sustainability value of stream flows in the lower reach.

Stream flow in the main stem of the Verde River is controlled by releases from two reservoirs (Horseshoe and Bartlett Lakes) near the lower end of the river. Operating rules for these reservoirs result in similar stream flow patterns between a gage upstream of the reservoirs and a second gage below the reservoirs except for higher stream flows during the summer at the downstream site. Mean monthly stream flows at these sites are displayed in figure 42. Mean monthly stream flows in the figure reflect the period from 1945 to 2014. Impacts of the reservoirs on the Verde on ecological sustainability are less than those of the reservoirs on the Salt River due to similar stream flow patterns between mean monthly stream flows at the above and below reservoir sites on the Verde River.

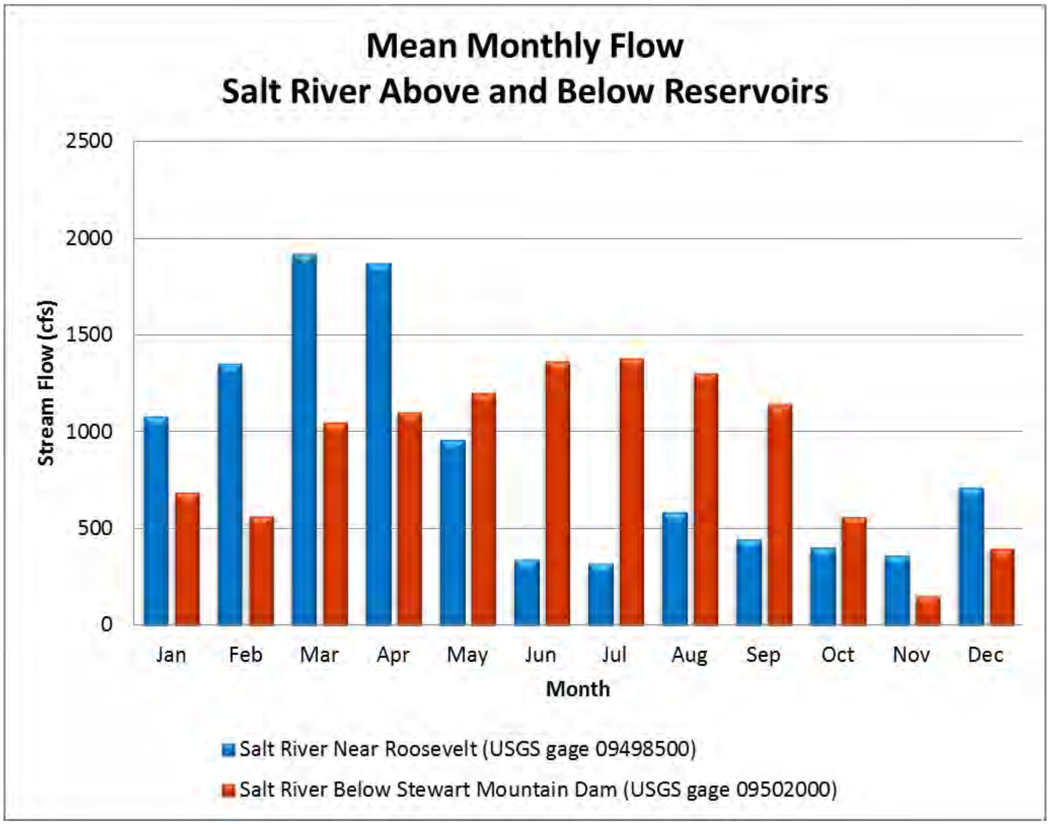


Figure 41. Salt River mean monthly flow (source: USGS 2014)

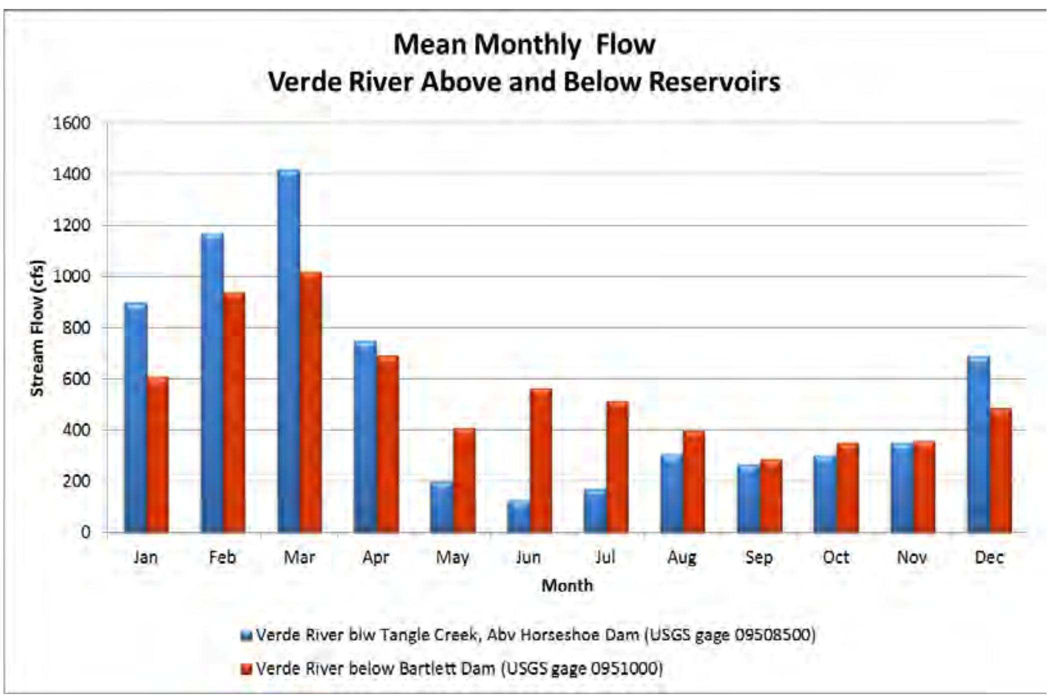


Figure 42. Verde River mean monthly flow (source: USGS 2014)

In addition to the effect of reservoirs on the annual distribution of stream flows they also affect the movement of nutrients and sediment through the river system. Stream bottom materials typically coarsen over time below reservoirs due to interruption of the natural sediment transport processes in the river. Sediments transported by the river deposit in the reservoir and are eroded below the reservoir. Reservoirs can also have water quality impacts, particularly on water quality constituents such as nutrients, temperature, and dissolved oxygen (Postel and Richter 2003, Graf 2006, Hadley and Emmett 1998).

A number of smaller dams also occur on Tonto National Forest. Inspiration Dam on Pinal Creek and Simpson Dam on Pinto Creek are examples. These structures are fully silted in, as are many other smaller dams. These dams and approximately 1,500 stock tanks that also have been constructed on the Tonto National Forest have smaller impacts on the ecological sustainability values of the channels they affect.

Historical Disturbances

Dams and impoundments did not exist prior to arrival of European settlers.

Water Withdrawals

Current Disturbances

Surface water withdrawals from streams reduce stream flows. Groundwater withdrawals by wells may also affect stream flow. Table 71 displays average annual surface water diversion and groundwater pumping by groundwater basins within selected Arizona Department of Water Resources Water Atlas (ADWR 2010) planning areas. Groundwater basin boundaries differ from the subbasins and watersheds used for much of the forest plan watershed assessment effort (see "Groundwater" on page 291). The Salt River basin described in the Atlas includes the Salt River watershed above Stewart Mountain Dam (Saguaro Lake) except for the Tonto Creek subbasin. The Verde River basin includes the watershed area above Bartlett Dam and most of the Sycamore Creek watershed. The remainder of the Verde watershed lies within the active management area planning area of the Atlas. The Agua Fria basin does not include the New River or Cave Creek watershed portions of the Agua Fria subbasin. These areas also lie within the active management area planning area. The active management area planning area also includes the Salt River below Saguaro Lake watershed within the Lower Salt subbasin, the Upper, Middle, and Lower Queen Creek watersheds and a portion of the Paisano Wash-Gila River watershed, all within the Middle Gila subbasin. The withdrawals displayed in table 71 is for the period 2001 to 2005.

Table 71. Average annual water withdrawals (2001-2005)

Watershed	Surface Water Diversions (acre-feet)	Ground Water Pumping (acre-feet)
Salt River	11,600	13,100
Tonto Creek	1,000	3,050
Verde River	17,400	29,500
Agua Fria River	0	3,300

Source: http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/default.htm

The San Carlos subbasin is not included due to the small portion within the Tonto National Forest. The city of Globe operates a water supply well field that pumped an estimated 1,600 acre-feet of water for municipal purposes in 2006 (ADWR 2010). Four of the five wells in the well field lie within the San Carlos subbasin. The Middle Gila subbasin was also not included due to the small area and low level of development within the Tonto National Forest portion of the subbasin. The portions of the Tonto within the active management area planning area of the Atlas are not included because the Phoenix metropolitan area and Salt River Valley water users overwhelm the surface water and groundwater disturbances within the planning area. Disturbances on the Tonto National Forest within this planning area include:

- Groundwater pumping for mining, domestic, and stock water uses, and to maintain a small lake at Boyce Thompson Arboretum in the Upper Queen Creek watershed.
- Minimal amounts of groundwater pumping for small scale uses in the Salt River below Saguaro Lake watershed.
- Water diverted from springs in the Camp Creek-Verde River watershed to supply domestic water to recreational residences along Upper Camp Creek.
- Diversions from springs in Seven Springs Wash and Walnut Springs Canyon in the Cave Creek watershed for irrigation of a small parcel of land, a bottled water operation, and domestic uses.

The New River watershed is not disturbed by surface water diversions or groundwater pumping on the Tonto National Forest.

The Middle Verde River upstream of the Tonto National Forest experiences the greatest volume of surface water diversions and groundwater pumping. Surface water diversions from the Verde River in the Middle Verde Valley (Clarkdale to Camp Verde) for irrigation uses have been present since the 1870s and sometimes reduce flows in portions of the Verde River to a trickle during irrigation season. These disturbances may impact streamflows within the reach of the Verde River on the Tonto.

Fossil Creek was affected by diversions to generate power at small hydroelectric plants at Irving and Childs from the early 1900s to 2005. The creek was nearly dewatered from a short distance below the springs that feed Fossil Creek to the Irving Power Plant approximately 4 miles downstream from the diversion dam. Approximately 5 cubic feet per second were discharged to Fossil Creek at Irving. The remainder of the approximately 43 cubic feet per second were conveyed to the power plant at Childs and discharged into the Verde River approximately 3.5 miles above the confluence with Fossil Creek. In 2005, the power plants were decommissioned and full flows were returned to Fossil Creek. Historically the springs maintained travertine structures in the channel by depositing calcium carbonate. Travertine structures were lost during the period when stream flows were diverted due to erosion by flood flows. Decommissioning of the power project allowed travertine structures to rebuild and the rebuilding process continues today. Restoring full flows has improved the ecological sustainability of resources supported by these flows and helped permit a native fish community to flourish in the stream (a fish barrier approximately 9 miles below the springs helps prevent nonnative fish species from competing with and preying on native species).

The East Verde River is affected by transbasin diversions that divert water from C.C. Cragin Reservoir (formerly Blue Ridge Reservoir) into the East Verde River near Washington Park. These diversions were intended to repay senior water right holders in the Salt River Basin (primarily Salt River Project) for water diverted out of the basin from the Black River to mines near Morenci. Imports occurred primarily during the spring, summer, and fall and increased base flows in the East Verde River substantially. Since passage of the Arizona Water Settlements Act in 2004, imports to the East Verde River are used to satisfy obligations to the Gila River Indian

Community and supplement Salt River Project shareholder water supplies. The Act authorized 3,500 acre-feet annually for northern Gila County communities and the city of Payson is currently constructing a pipeline from the outlet of the C.C. Cragin pipeline to the city. Figure 43 displays mean monthly stream flows measured in the East Verde River near the confluence with the Verde River (USGS Gage - East Verde River near Childs) from 1961 to 2014 and the mean monthly flow imported into the East Verde River headwaters from C.C. Cragin Reservoir (USGS Gage- East Verde River Diversions from East Clear Creek near Pine) from 1965 to 2014. The chart clearly displays the impact of the imports on base flows in the East Verde River particularly during the summer and fall. As a result of the Arizona Water Settlements Act, imports to the East Verde will continue but at a reduced rate.

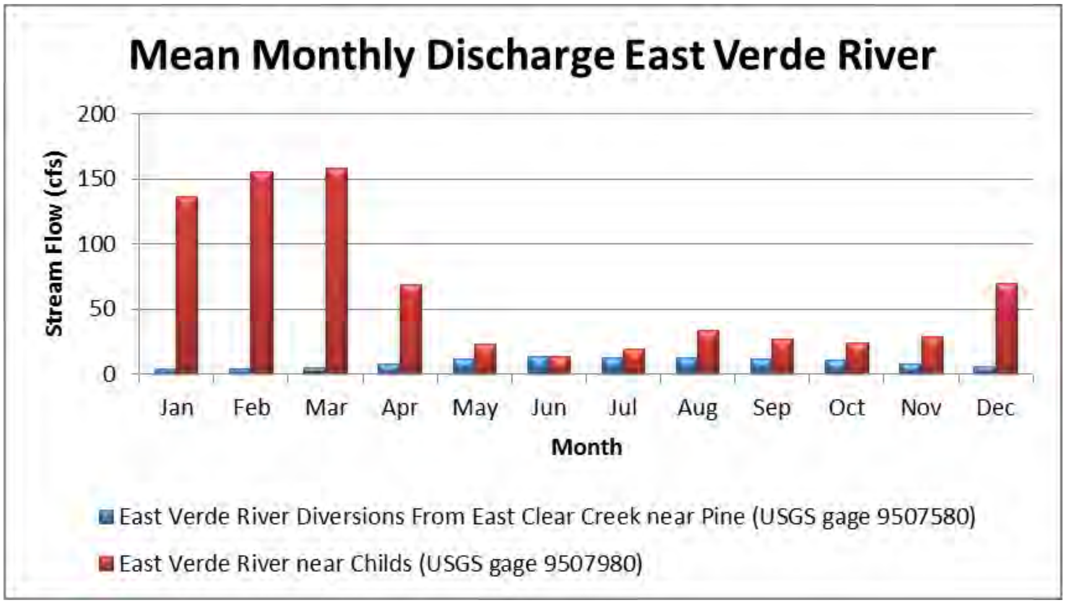


Figure 43. East Verde River mean monthly discharge (source: USGS 2014)

Small-scale diversions occur from many of the perennial streams, or springs feeding these streams, that originate below the Mogollon Rim to provide water to private lands located along these streams. Groundwater pumping on private lands also occurs in proximity to many streams and may also impact streamflows. Diversions for fish hatcheries affect short reaches of Tonto and Canyon Creek. A well field authorized on the Tonto for widening and realigning Highway 260 from Payson to Heber affects nearby springs and a stream. Mitigation measures for the well field include a diversion from Tonto Creek that allows withdrawals from the creek during the winter and spring if specific flow conditions are met in the creek. Water from the creek is used to artificially recharge the aquifer affected by pumping.

Stream diversions from Cherry Creek on the far east side of the Tonto National Forest, Tonto Creek above Gisela, Deer Creek near Rye, and Pine Creek above Pine reduce base flows or dewater reaches of these creeks below the diversions.

Large mines exist in the Globe-Miami and Superior areas. Groundwater pumping by these mines may affect stream flows in Pinal and Pinto Creeks. Impacts to streamflow from groundwater pumping by the Carlota Copper Mine were documented in a perennial tributary to Pinto Creek (USDA Forest Service 1997). In addition to the pumping impacts, mines can also affect groundwater flow paths through development of pits in open pit mines and by tunnels, shafts, adits, etc. in underground mines. Both types of mines are found as either abandoned or currently operating mines on the Tonto National Forest. An additional large mine (Resolution Copper Mine) is proposed on the Tonto in the near future. The Resolution Copper Mine is proposed as an underground mine but would be expected to have subsidence effects at the surface.

Historical Disturbances

Although development of groundwater began with shallow wells dug by the Hohokam Indians at least a thousand years prior to European settlement (Harshbarger 1966), large-scale development of groundwater resources did not begin until the development of centrifugal pumps and internal combustion engines near the turn of the 19th century (Glennon 2002). Consequently, streamflows and groundwater systems were most likely dictated by climatic conditions. Native Americans were known to have constructed canals that diverted water from Tonto Creek, Salt River, Verde River, Cherry Creek, Pinal Creek, and Rye Creek. Other canals may also have existed within the Tonto National Forest. These diversions would most likely have affected base flows in streams during the summer irrigation season.

Drought

Current Disturbances

Periodic droughts have been reported since the arrival of European settlers. Figure 44 displays a running 10-year average precipitation versus long-term average precipitation for Climate Division 4 (Gila County) in Arizona. Data used for the figure begins in 1895 and ends in 2013. The figure displays the extreme drought that occurred at the turn of the 19th century from about 1891 to 1904 (Webb et al. 2007). It also displays a drought period in the 1950s and the severity of the most recent drought that began in the middle 1990s. The figure also displays wet periods in the 1910s to 1920s and from the late 1970s to early 1990s.

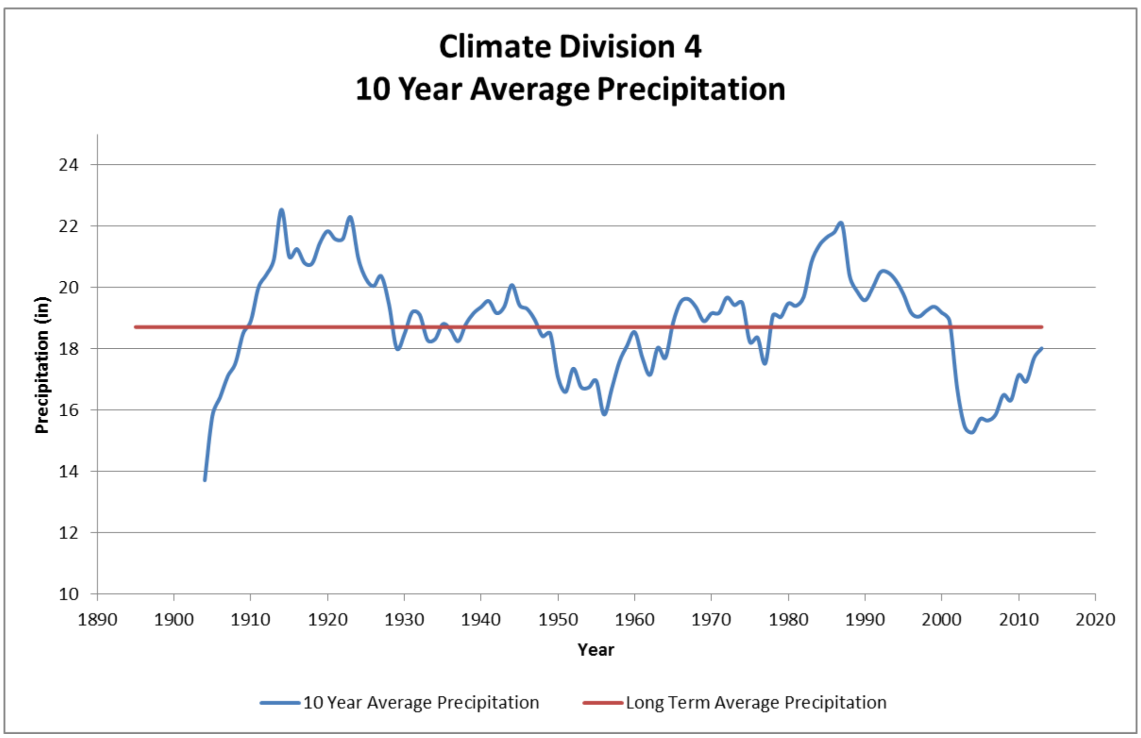


Figure 44. Ten-year average precipitation, Climate Division 4 (Gila County) (source: WRCC 2014)

Periods of drought result in reduced streamflow and can result in reduced vegetative groundcover that exposes soils to increased erosion and sediment delivery to stream channels during storm events. Drought can also increase the risk of catastrophic wildfire due to the low moisture content of drought-stressed vegetation. Wildfires can also increase the likelihood of much higher than normal peak flows and soil erosion during storm events due to the loss of vegetation protecting the soil surface and development of water repellant soils (DeBano et al. 1998).

Extended periods of below normal streamflow and low reservoir levels in the late 1990s and early 2000s identify this period as one of the driest in the period of observed stream flow records in the Salt-Verde watershed (Hirschboeck and Meko 2005). Hirshboeck and Meko (2005) compared streamflow data from the U.S. Geological Survey gage on the Salt River near Roosevelt, which has recorded streamflow data from 1914 to present with tree ring reconstruction of stream flows for the Salt-Verde watersheds that date back to A.D. 1199. They found the recent drought is comparable to that experienced in the 1950s. The reconstructed streamflow record suggests the recent drought was exceeded in severity several times in the past 800 years.

Figure 45 displays the 5-year average precipitation reconstruction for Arizona Climate Division 4. Values are expressed as a percentage of 1000 to 1988 average precipitation. Adjusted 1955 to 1959 and 1999 to 2003 averages for the climate division are provided for comparison (orange and red lines respectively). These two periods correspond to the driest 5-year spans in the two most severe droughts in the instrumented record (Climate Assessment for the Southwest 2014). This figure displays several periods over the reconstructed record where extended dry periods stand out, particularly the late 1000s to early 1100s, late 1200s, early 1300s, late 1500s, late 1700s, and the mid 1900s (Climate Assessment for the Southwest 2014).

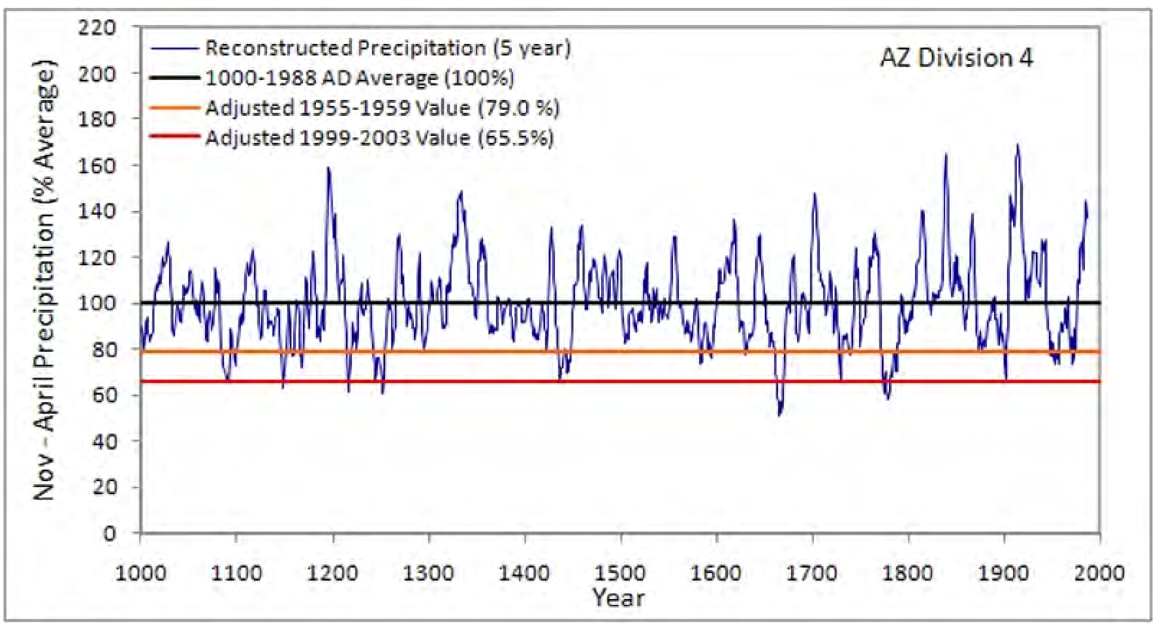


Figure 45. 5-year average precipitation, reconstructed from 1000 A.D. to 1988
Source: http://www.climas.arizona.edu/az-climate-division-4-climate-reconstructions

Historical Disturbances

Periods of drought are known to have occurred during historic conditions due to tree ring evidence that reconstructs past climatic and hydrologic conditions (Meko et al. 1995). Tree ring evidence records several severe droughts in the Southwest from A.D. 512 to 1673 (Meko et al. 1995). Some studies suggest periods of drought may be responsible for arroyo cutting in the Southwest (Webb et al. 2007). The period of most recent arroyo cutting in the Southwest began in the 40-year period from around 1862 through 1909, with most of the change beginning in the 1880s and early 1890s.

> "Several human-introduced factors exacerbated the climatic forcing of arroyo down cutting. Livestock grazing undoubtedly had local impacts, possibly on a watershed scale and certainly on floodplains. Irrigation canals and roads channeled flow on floodplains, plotting the locations of future gullies and arroyos. In-stream gravel mining may renew channel down cutting and knickpoint migration."(Webb et al. 2007).

Flooding

Current Disturbances

Flooding is a regular disturbance to rivers and streams throughout the Tonto National Forest and is an important contributor to ecosystem sustainability. Floods scour channels and floodplains, which can both remove riparian vegetation and provide recruitment surfaces for new riparian vegetation. They recharge alluvial aquifers that can discharge during dry periods of the year to support base flows in streams, and they can preferentially select for native aquatic species that are better adapted to flooding conditions characteristic of the Southwest than are nonnative aquatic species. Frequent floods (floods with recurrence intervals of 1 to 2 years) are important for maintaining channel and floodplain geometry (Rosgen 1996).

Floods can have damaging effects on channels and floodplains as well, particularly those with unstable conditions. High shear stresses on banks can induce lateral channel changes at the expense of floodplain area and floodplain vegetation (Webb et al. 2007). Floods can also cause channel downcutting that lowers the water table in adjacent floodplains and can result in mortality to floodplain riparian vegetation.

Peak flow data from the U.S. Geological Survey gage on the Verde River below Tangle Creek (gage no. 09508500) indicates that approximately two-thirds of the annual peak flows occur during the winter and spring period from general frontal storms (several of which were fueled by El Niño conditions). Winter and spring peak flows are also of greater magnitude than those that occur during the summer and fall period. The 10 highest peak flows occurred during winter and spring period. The largest gaged flood at this site was 145,000 cubic feet per second in January 1993. This flood has a recurrence interval of between 50 and 100 years. A slightly larger flood (150,000 cubic feet per second) was estimated for February 1891.[3] Median peak flows during the winter and spring period are 22,900 cubic feet per second, somewhat greater than a 2-year flood, while median peak flows during the summer and fall period are only 6,910 cubic feet per second, which is equivalent to the mean annual flood. Higher peak flows in smaller watersheds can occur from high-intensity summer thunderstorms that are generally of limited aerial extent.

[3] http://nwis.waterdata.usgs.gov/az/nwis/peak?site_no=09508500&agency_cd=USGS&format=html

Historical Disturbances

Flooding occurred on streams and rivers within the area that is now the Tonto National Forest prior to the arrival of Europeans. A paleoflood study conducted by House et al. (2002) documented the occurrence of at least 11 major floods on the Verde River dating back to at least 1400 to 1600 years before present. Evidence of smaller paleofloods would have been obscured by large floods that have occurred under current conditions. Ely et al. (1993) and Ely (1997) evaluated flood history over the last 5,000 years in the Southwest and reported that the largest floods cluster into distinct time periods that are related to regional and global climatic fluctuations. They reported that episodes with increased frequency of high magnitude floods coincide with periods of cool, wet climate whereas warm intervals are times of dramatic decreases in the number of large floods. They found a positive relationship between paleofloods and long-term variations in the frequency of El Niño events.

Prescribed Fire and Wildfire

Current Disturbances

Prescribed fires generally have little impacts on water resources due to low burn intensities. Uncharacteristically severe wildfires, on the other hand, can have profound impacts on water resources due to interactions of fuels, soils, slope, and climate. The most recent significant fire on the Tonto National Forest was the Sunflower Fire, which burned 17,600 acres in 2012. This fire resulted in high peak flows and transport of sediment and ash that challenged the city of Phoenix water filtration system. Fires in the Southwest typically occur during hot dry periods when fuel moisture and humidity are low. When coupled with the uncharacteristically high amounts of fuel, they result in high burn severity. Loss of soil vegetative cover and organic matter, changes in soil properties, steep slopes, and geology, combined with high-intensity thunderstorms that follow soon after wildfires, result in large increases in peak flows (Swanson 1981 in Neary, Gottfried, and Viegas 2002). Impacts are greatest in mixed conifer, ponderosa pine, and chaparral watersheds. Lesser effects are seen in pinyon-juniper, grassland, and desert watersheds. The spread of red brome, a nonnative annual grass, into the Sonoran Desert ecosystem has changed fire regime characteristics; fires are greater in areal extent and more frequent than prior to introduction of this species. Fire characteristics in the ponderosa pine vegetation type have also changed due to greater fuel densities. Wildfires in ponderosa pine forests burn with greater intensity and severity than prior to arrival of Europeans, and watershed responses have also increased. Post-wildfire watershed responses include increased erosion and delivery of ash and sediment to stream channels, impacts to water quality, and impacts to stream channel geometry, in addition to increased runoff and peak flows. Watershed responses typically return to pre-fire conditions within 1 to 10 years following a wildfire, depending on fuel type (more quickly in grasslands and more slowly in ponderosa pine and mixed conifer; Baker 1988 and Neary et al. 2005).

Historical Disturbances

Native Americans were known to use fire for hunting under historic conditions (Allen 2002). Fuel buildup in the Pinyon-Juniper and Ponderosa Pine ecological response units were probably less under historic conditions than under current conditions due to the presence of a more natural and frequent fire regime. Exclusion of wildfires have increased fuel loadings that result in more damaging wildfires under current conditions than under historic conditions. Absence of red brome in the Sonoran Desert under historic conditions probably reduced the frequency and aerial extent of wildfire in this fuel type. Watershed responses to wildfires were probably less severe under the more natural fire regime that existed historically.

Water Rights

The Tonto National Forest has filed numerous claims and applications for water rights within the boundaries of the national forest; the Arizona Department of Water Resources issues and manages water rights within the state. Most of these claims are for springs, stock tanks, and wells to provide water for livestock and wildlife. The Tonto has filed approximately 3,200 applications and claims for springs and stock tanks on National Forest System lands within its boundary. To reduce the likelihood of impacts from water withdrawals and maintain streamflow in many of the streams threatened by dewatering or with substantial resource values (such as threatened and endangered species), Tonto National Forest personnel have filed a number of instream flow water right applications with the Arizona Department of Water Resources. Instream flow water rights are a type of water right recognized by the state of Arizona specifically for supporting the beneficial uses of wildlife, including fish and for recreation. Instream flow water rights are nonconsumptive rights that seek to maintain flow in the stream channel. In general, the applications submitted by Tonto National Forest personnel seek to maintain median monthly flows in specific stream reaches. A map displaying the status of streams with instream flow claims on the Tonto National Forest is displayed in figure 46. To date, the Tonto National Forest has received water right certificates for 12 stream reaches including the Lower Verde River and Fossil Creek, among others. Instream flow assessments have been completed for another 10 stream reaches. Instream flow permits for these streams await resolution of protests or review of the instream flow assessments by the Arizona Department of Water Resources. Streams with instream flow water right applications or certificates are displayed in table 72 and table 73.

Table 72. Stream reaches with instream flow water right certificates

Stream Name	Application Number	Priority Date	Flow Range Protected (cubic feet per second)*
Arnett Creek	33-96235	10/20/1992	0.1 - 2.8
Camp Creek	33-96693	7/5/2001	0.05 - 0.3
Cave Creek	33-96302	9/27/1993	0.5 - 17.3
Cherry Creek	33-96609	6/30/1999	Reach 1: 1.24 – 11.16 Reach 2: 6.9 – 31.0
Christopher Creek	33-96575	4/23/1998	0.6 - 15.7
East Verde River	33-90310	11/26/1985	1.8 - 7
Fossil Creek	33-96622	12/1/1999	42.5 - 51.1
Pinto Creek	33-89109	12/14/1983	1.2 - 5.5
Reynolds Creek	33-96570	10/31/1997	0.04 - 9.2
Seven Springs Wash	33-96303	9/27/1993	0.4 - 1.0
Sycamore Creek	33-96509	3/15/1996	0.1 - 13.0
Verde River	33-90309	11/26/1985	4.0 - 65.0 at Beasly Flat 70 - 135 at Red Creek

* Flows certificated vary by month and this column displays the range from the month with the lowest flow to that with the greatest flow.

Table 73. Stream reaches with instream flow water right applications

Stream Name	Application No.	Priority Date
Canyon Creek	33-96816	9/30/2005
Coon Creek	33-96742	6/18/2003
Haigler Creek	33-96571	10/31/1997
Pine Creek	33-96917	5/13/2010
Red Creek	33-96743	6/18/2003
Spring Creek	33-96815	9/28/2005
Tangle Creek	33-96859	1/31/2007
Tonto Creek	33-96684	11/15/2000
Webber Creek	33-96923	5/13/2010
Workman Creek	33-96618	12/15/1999

In addition to instream flow water rights, the Tonto National Forest also has applications, claims, or certificates for approximately 1,850 springs within its boundary. Applications for water rights for springs are typically intended to provide water for livestock and wildlife and sometimes include domestic and recreational uses. If Tonto National Forest personnel receive certificates for these springs, it will ensure water from these springs will remain on the Tonto. Developments that divert water from the spring source can affect ecological values supported by the springs.

The Tonto National Forest has water right applications or certificates for approximately 1,340 stocktanks as well. Stocktanks typically are constructed to provide water for livestock to improve livestock distribution but can also provide water for wildlife.

Two wild and scenic rivers are located partly on the Tonto: Verde River and Fossil Creek. When wild and scenic rivers are designated the volume of water necessary to preserve the outstandingly remarkable values associated with the rivers is reserved by the Federal government. The volume of water necessary to preserve the outstandingly remarkable values has not yet been quantified for either river but will provide additional flow protection once quantification is completed.

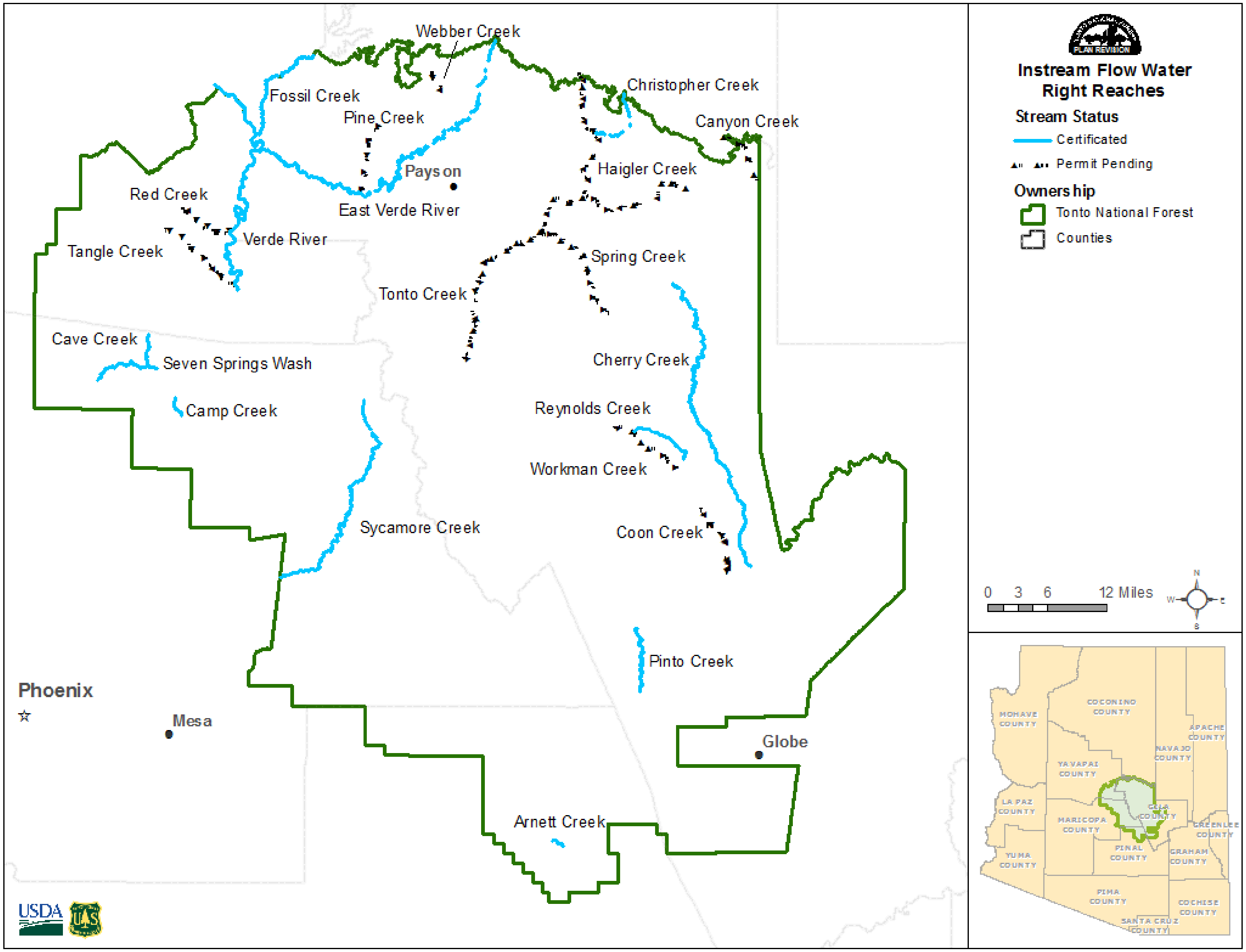


Figure 46. Stream reaches with instream flow water right certificates or pending permits on the Tonto National Forest

Reference Conditions

Limited information is available on the natural range of variation and extent of perennial streams prior to arrival of Europeans. A period of arroyo cutting began around the mid 1880s and extended through the early 1940s due to an increase in the frequency and severity of floods (Webb et al. 2007). A number of factors may have contributed to downcutting during this period: overgrazing, drought, a period of unusually large storms of regional extent that caused some extraordinary floods during the period, and changes in the seasonal pattern of precipitation during the 20th century (Webb et al. 2007). In the absence of knowledge about the natural range of variation and extent of perennial streams and departure from the natural range of variation, an alternative method to assess the natural range of variation was used. Representativeness and redundancy were used as metrics to assess ecosystem integrity of each watershed (USDA Forest Service 2013).

Characteristics of representativeness:

- Are designed to indicate representation of the full array of potential conditions and variations of conditions (states) of an ecosystem characteristic on the landscape.
- Are accomplished by evaluating the proportional occurrence of an ecosystem characteristic at the Tonto National Forest (watershed) scale compared to that found at a scale above the planning unit (subbasin), and then evaluating whether these characteristics are under or over-represented within the national forest.
- Are based on three assumptions:
    1. There is a “representative” range of specific hydrologic feature conditions associated with an ecosystem characteristic across the larger landscape.
    2. A wide range of hydrologic feature conditions will sustain the greatest percentage of the component species which utilize that characteristic.
    3. A higher representativeness, leading to presence of more variety of conditions, creates a more sustainable ecosystem.

Representativeness of perennial streams within the Tonto National Forest was assessed at the subbasin and watershed scales. Representativeness was assessed by developing an index that is derived by dividing the percent of perennial stream miles on the Tonto National Forest in each subbasin or watershed by the percent of watershed area on the Tonto within each subbasin or watershed. The resulting index numbers were rated as:

- less than 0.8 = underrepresented,
- 0.8 to 1.2 = proportional, and
- more than 1.2 = overrepresented.

Characteristics of redundancy:

- Ensure that there are multiple occurrences of representative conditions across the landscape.
- Assume that finding the occurrence of an ecosystem characteristic in multiple places across the landscape increases the likelihood of maintaining representativeness by decreasing the risk of eliminating the characteristic or a specific condition of the characteristic through a single disturbance event.
- Are calculated by computing the miles of perennial streams that should be within each watershed if perennial stream miles are evenly distributed throughout a subbasin.

Subbasin redundancy ratings are described as:

- low (hydrologic feature is not found in each watershed within the subbasin);
- moderate (hydrologic feature is found in each watershed but is not evenly distributed between watersheds); and
- high (hydrologic feature is found in each watershed and is approximately evenly distributed between them).

Table 74 displays representativeness of perennial stream miles by subbasin. The table shows perennial streams on the Tonto are underrepresented on the three subbasins that include a small percent of Tonto National Forest-administered lands in the subbasin. Perennial stream miles on National Forest System lands within the three subbasins where Tonto National Forest-administered lands occupy more than 50 percent of the subbasin areas are considered proportional to the miles of perennial streams within the subbasin as a whole. Perennial stream miles on the Tonto are considered overrepresented in only the Lower Salt subbasin. This is probably due to diversion of perennial flow in the Salt River into canals at Granite Reef Diversion Dam and the extensive residential and agricultural development on the portion of the subbasin outside the national forest. On an overall basis, the perennial stream miles on the Tonto National Forest are considered overrepresentative of the seven subbasins due to the small percent of subbasin watershed area within the Tonto and the large number of perennial stream miles on the Tonto. The three subbasins where perennial stream miles on the Tonto National Forest are underrepresented provide only 20 percent of the perennial stream miles in the context area. The three subbasins where perennial stream miles on the Tonto are proportional to those in the subbasin provide more than 75 percent of the perennial stream miles in the context area. When the small percent of subbasin area on the national forest (34 percent) is compared with the large percent of perennial stream miles on the national forest (52 percent) then perennial stream miles on the Tonto are overrepresented in the context area.

Table 74. Tonto National Forest (NF) perennial stream representativeness by subbasin

Subbasin	Subbasin area (square miles)	Tonto NF area in Subbasin (square miles)	Tonto NF area in Subbasin (%)	Perennial Stream Miles in Subbasin	Perennial Stream Miles in Tonto NF	Perennial Stream Miles in Tonto NF as % of Subbasin	Representativeness Index	Representativeness Rating
San Carlos	1,075	98	9.1%	36.1	0	0.0%	0.00	Under
Middle Gila	3,326	260	7.8%	94.2	2.2	2.3%	0.30	Under
Upper Salt	2,152	1,197	55.6%	265.6	125.1	47.1%	0.85	Proportional
Tonto	1,048	1,038	99.0%	119.6	119.6	100.0%	1.01	Proportional
Lower Salt	997	457	45.9%	22.4	14	62.5%	1.36	Over
Lower Verde	1,965	1,297	66.0%	284.7	184	64.6%	0.98	Proportional
Agua Fria	2,766	286	10.4%	44.7	3	6.7%	0.65	Under
Totals	**13,330**	**4,634**	**34.8%**	**867.3**	**447.9**	**51.6%**	**1.49**	**Over**

Note: Perennial stream miles do not include stream miles through reservoirs or lakes

Table 75. Derivation of even stream distribution by watershed

Subbasin	Subbasin Code	Perennial Streams Miles in Tonto NF	Number of watersheds	Even Stream Distribution* (miles)
San Carlos	15040007	0.0	4	NA
Middle Gila	15050100	2.2	11	0.2
Upper Salt	15060103	125.1	9	13.9
Tonto	15060105	119.6	5	23.92
Lower Salt	15060106	14	3	4.67
Lower Verde	15060203	184	7	26.29
Agua Fria	15070102	3	9	0.33
Totals	not applicable	447.9	48	9.33

* Determined by dividing stream miles within the Tonto National Forest in each subbasin by number of watersheds in subbasin

Representativeness of perennial streams are displayed by watershed in table 76 and summarized in table 77. Redundancy ratings are displayed in table 78 and are based on the assessment of even distribution of perennial stream miles developed in table 75 and table 77.

Table 76. Representativeness of perennial streams within watersheds on the Tonto National Forest (NF)

Subbasins and Watersheds	Watershed area (square miles)	Tonto NF Watershed Area (square miles)	Tonto NF Watershed Area (%)	Perennial Stream Miles[1] in Watershed	Perennial Stream Miles in Tonto NF	Perennial Stream Miles in Tonto NF as % of Watershed	Representative-ness Index[2]	Representative-ness Rating
San Carlos Subbasin								
Sevenmile Wash-Sycamore Creek	253	58	23.1%	0.00	0.00	not applicable	not applicable	not applicable
Gilson Wash	245	40	16.2%	0.00	0.00	not applicable	not applicable	not applicable
Middle Gila Subbasin								
Dripping Springs Wash-Gila River	393	5	1.3%	33.10	0.00	0.0%	0.00	Under
Mineral Creek-Gila River	259	55	21.3%	25.16	0.00	0.0%	0.00	Under
Box O Wash-Gila River	298	4	1.5%	21.80	0.00	0.0%	0.00	Under
Upper Queen Creek	143	143	99.4%	2.19	2.19	100.0%	1.01	Proportional
Paisano Wash-Gila River	374	2	0.4%	>0.01	0	0.0%	0.00	Under
Middle Queen Creek	381	49	12.9%	0.00	0	not applicable	not applicable	not applicable
Lower Queen Creek	157	2	1.3%	0.00	0	not applicable	not applicable	not applicable
Upper Salt Subbasin								
Sawmill Creek-Salt River	267	17	6.2%	40.78	0.92	2.3%	0.36	Under
Canyon Creek	318	66	20.6%	57.83	9.82	17.0%	0.82	Proportional
Cherry Creek	278	265	95.3%	40.89	40.76	99.7%	1.05	Proportional
Salt River Draw-Salt River	236	132	55.8%	30.28	15.88	52.4%	0.94	Proportional
Pinal Creek	200	155	77.5%	9.48	7.45	78.6%	1.01	Proportional
Pinto Creek	186	186	100%	5.54	5.54	100.0%	1.00	Proportional
Salome Creek	119	119	100%	17.44	17.44	100.0%	1.00	Proportional
Salt River-Theodore Roosevelt Lake	259	259	100%	27.30	27.30	100.0%	1.00	Proportional
Tonto Subbasin								
Spring Creek	147	147	100%	8.97	8.97	100.0%	1.00	Proportional
Haigler Creek-Tonto Creek	224	214	95.5%	67.39	67.38	100.0%	1.05	Proportional
Rye Creek-Tonto Creek	301	301	100%	32.49	32.49	100.0%	1.00	Proportional

Subbasins and Watersheds	Watershed area (square miles)	Tonto NF Watershed Area (square miles)	Tonto NF Watershed Area (%)	Perennial Stream Miles[1] in Watershed	Perennial Stream Miles in Tonto NF	Perennial Stream Miles in Tonto NF as % of Watershed	Representative-ness Index[2]	Representative-ness Rating
Gun Creek-Tonto Creek	283	283	100%	10.31	10.31	100.0%	1.00	Proportional
Tonto Creek-Theodore Roosevelt Lake	93	93	100%	0.50	0.50	100.0%	1.00	Proportional
Lower Salt Subbasin								
Salt River-Apache, Canyon, and Saguaro Lake	388	388	100%	0.00	0.00	not applicable	not applicable	not applicable
Indian Bend Wash	221	1	0.4%	0.00	0.00	not applicable	not applicable	not applicable
Salt River below Saguaro Lake	431	68	15.7%	21.90	13.90	63.5%	4.03	Over
Lower Verde Subbasin								
East Verde River	331	317	95.8%	83.17	82.64	99.4%	1.04	Proportional
Fossil Creek-Verde River	299	62	20.8%	52.08	13.14	25.2%	1.21	Over
Tangle Creek-Verde River	278	278	100%	39.59	39.59	100.0%	1.00	Proportional
Verde River-Horseshoe and Bartlett Reservoir	300	300	100%	28.30	28.30	100.0%	1.00	Proportional
Sycamore Creek	193	190	98.7%	9.67	9.23	95.5%	0.97	Proportional
Camp Creek-Verde River	266	150	56.3%	29.05	11.81	40.7%	0.72	Under
Agua Fria Subbasin								
Sycamore Creek-Agua Fria River	366	105	28.6%	21.32	0.28	1.3%	0.05	Under
Agua Fria River-Lake Pleasant	372	11	3.1%	3.65	0.00	0.0%	0.00	Under
Cave Creek-Arizona Canal Diversion Channel	285	89	31.1%	2.67	2.67	100.0%	3.22	Over
New River	363	82	22.5%	0.00	0.00	not applicable	not applicable	not applicable
Total	**9507**	**4634**	**48.7%**	**723**	**448.5**	**62.1**	**1.27**	**Over**

1. Perennial stream miles are based on National Hydrological Dataset layer from Arizona Department of Water Resources but do not include stream miles through reservoirs or lakes.
2. Representativeness is not assessed where there are no perennial streams within the watershed.

Table 77. Summary of representativeness ratings of perennial stream miles within 5th-level watersheds containing portions of the Tonto National Forest compared to total watershed area

Representativeness	Number of Watersheds
Proportional	16
Underrepresented	8
Overrepresented	3
Not Assessed*	7

* Perennial stream miles do not occur within these watersheds

Table 76 and table 77 show there are 8 watersheds where perennials stream miles on the Tonto National Forest are underrepresented, two watersheds where perennial stream miles are overrepresented, 18 watersheds where the miles of perennial streams on the national forest are proportional to the miles in the entire watershed, and 7 watersheds that were not rated because perennial streams do not occur. The Tonto National Forest as a whole is overrepresented in terms of perennial streams for reasons similar to those for the 4th-level context area. The watersheds that do not support any miles of perennial streams or where the Tonto National Forest is rated as underrepresented comprise 48 percent of the 5th-level planning unit area but provide only 24 percent of the perennial stream miles. The 5th-level watersheds rated as proportional or overrepresented in terms of perennial stream miles provide 52 percent of the planning unit watershed area but 76 percent of the perennial stream miles.

Table 78 shows redundancy is low in four of the subbasins due to a number of watersheds within those subbasins that do not support any perennial streams. Redundancy is rated as moderate in the remaining subbasins. All watersheds within these subbasins support perennial streams but they are not evenly distributed within the watersheds. For perennial streams to be evenly distributed through the watersheds in the Lower Verde subbasin, for example, each watershed would be expected to contain close to 41 miles of perennial streams. Perennial stream miles actually range from less than 10 miles in the Sycamore Creek watershed to more than 80 miles in the East Verde River watershed.

Table 78. Redundancy assessment of perennial streams within subbasins of the Tonto National Forest (NF)

Subbasin and Watersheds	Watershed Number	Tonto NF Perennial Streams (miles)	Even Distribution (miles)	Deviation (miles)	Proportional Deviation	Redundancy
San Carlos Subbasin						
Sevenmile Wash-Sycamore Creek	1504000702	0.00	not applicable	not applicable	not applicable	not applicable
Gilson Wash	1504000703	0.00	not applicable	not applicable	not applicable	not applicable
Middle Gila Subbasin						
Dripping Springs Wash-Gila River	1505010001	0.0	0.2	0.2	1.00	low
Mineral Creek-Gila River	1505010002	0.0	0.2	0.2	1.00	low
Box O Wash-Gila River	1505010003	0.00	0.2	0.20	1.00	low

Subbasin and Watersheds	Watershed Number	Tonto NF Perennial Streams (miles)	Even Distribution (miles)	Deviation (miles)	Proportional Deviation	Redundancy
Upper Queen Creek	1505010004	2.19	0.2	-1.99	-9.93	low
Paisano Wash-Gila River	1505010007	0.00	0.2	0.20	1.00	low
Middle Queen Creek	150501000	0.00	0.2	0.20	1.00	low
Lower Queen Creek	1505010009	0.00	0.2	0.20	1.00	low
Upper Salt Subbasin						
Sawmill Creek-Salt River	1506010302	0.92	13.9	12.98	0.93	moderate
Canyon Creek	1506010303	9.82	13.9	4.08	0.29	moderate
Cherry Creek	1506010304	40.76	13.9	-26.86	-1.93	moderate
Salt River Draw-Salt River	1506010305	15.88	13.9	-1.98	-0.14	moderate
Pinal Creek	1506010306	7.45	13.9	6.45	0.46	moderate
Pinto Creek	1506010307	5.54	13.9	8.36	0.60	moderate
Salome Creek	1506010308	17.44	13.9	-3.54	-0.25	moderate
Salt River-Theodore Roosevelt Lake	1506010309	27.30	13.9	-13.40	-0.96	moderate
Tonto Subbasin						
Spring Creek	1506010501	8.97	23.92	14.95	0.62	moderate
Haigler Creek-Tonto Creek	1506010502	67.39	23.92	-43.47	-1.82	moderate
Rye Creek-Tonto Creek	1506010503	32.49	23.92	-8.57	-0.36	moderate
Gun Creek-Tonto Creek	1506010504	10.31	23.92	13.61	0.57	moderate
Tonto Creek-Theodore Roosevelt Lake	1506010505	0.50	23.92	23.42	0.98	moderate
Lower Salt Subbasin						
Salt River-Apache, Canyon, and Saguaro Lake	1506010601	0.00	4.67	4.67	1.00	low
Indian Bend Wash	1506010602	0.00	4.67	4.67	1.00	low
Salt River below Saguaro Lake	1506010603	13.90	4.67	-9.23	-1.98	low
Lower Verde Subbasin						
East Verde River	1506020302	82.64	26.29	-56.35	-2.14	moderate
Fossil Creek-Verde River	1506020303	13.14	26.29	13.15	0.50	moderate
Tangle Creek-Verde River	1506020304	39.59	26.29	-13.30	-0.51	moderate

Subbasin and Watersheds	Watershed Number	Tonto NF Perennial Streams (miles)	Even Distribution (miles)	Deviation (miles)	Proportional Deviation	Redundancy
Verde River-Horseshoe and Bartlett Reservoir	1506020305	28.30	26.29	-2.01	-0.08	moderate
Sycamore Creek	1506020306	9.23	26.29	17.06	0.65	moderate
Camp Creek-Verde River	1506020307	11.81	26.29	14.48	0.55	moderate
Agua Fria Subbasin						
Sycamore Creek-Agua Fria River	1507010204	0.28	0.33	0.05	0.14	low
Agua Fria River-Lake Pleasant	1507010205	0.00	0.33	0.33	1.00	low
Cave Creek-Arizona Canal Diversion Channel	1507010206	2.67	0.33	-2.34	-7.10	low
New River	1507010208	0.00	0.33	0.33	1.00	low

Trends and Projections

Population growth is expected to continue in the Middle and Upper Verde River watersheds (ADWR 2000). Growth and related development has the potential to impact availability of surface and groundwater (ADWR 2000). The most likely impact on the Tonto National Forest from upstream growth would be reduced base flows in the Verde River where it flows through the Tonto. The effects of proposed groundwater pumping from the Big Chino aquifer in terms of potential impact on base flow in the Verde River within the Middle Verde subbasin are controversial but impacts to the Verde River in this subbasin should they occur may also be felt in the Lower Verde River.

Potential for continued population growth in the Gila County communities of Pleasant Valley, Tonto Basin, and other unincorporated communities in the county also exists. Development would probably rely on groundwater pumping to provide water for growth. Increased groundwater pumping has the potential to impact base flows in perennial streams such as Tonto, Cherry, Pine, and Houston Creeks. Population growth and associated development in the Globe-Miami area would be most likely to affect base flows in Pinal Creek but much of the base flow in the creek is controlled by discharge from the water treatment system constructed to treat polluted groundwater migrating through the alluvium and geologic formations underlying the creek.

Springs and Stocktanks

Springs are a valuable but limited resource on the Tonto National Forest particularly in the more arid portions. Water discharged from springs supports riparian habitat and provides important water sources for wildlife, livestock, and human needs. Springs can also be an important source of base flows in perennial streams and can maintain stream flows during the hot summer months.

Stocktanks, although a man-made disturbance within the watershed, are also a valuable water source for livestock and wildlife. Stocktanks help to distribute livestock more evenly across the landscape and help reduce the effects of concentrated livestock use at more traditional watering sources such as intermittent and perennial streams, and springs and seeps.

The Tonto National Forest personnel are conducting an inventory of the Tonto's water sources, including springs and stocktanks. Data collected includes location, discharge, resource values, basic water chemistry, condition of riparian vegetation (if any) supported by the water source, and condition of constructed features associated with the water source (if any). Approximately 2,000 water sources have been inventoried to date.

Setting above Planning Unit

Table 79 displays watershed area and numbers of springs by subbasin for the entire subbasin and for the portion within the Tonto National Forest. Spring data is derived from cartographic feature files available from the U.S. Geological Survey. Data from cartographic feature files is less accurate than site-specific data available on the Tonto but allows data comparison at comparable scales both on and off the national forest.

Cartographic feature file data identify 1,687 springs within the subbasin context area and 1,024 springs within the exterior boundaries of the Tonto National Forest. At the subbasin level, the Tonto occupies about 35 percent of the land area but hosts 61 percent of the springs. The greater proportion of springs on the Tonto is most likely due to the mountainous topography, higher elevations, greater volume of precipitation, and proximity of the Tonto to groundwater recharge areas such as the Mogollon Rim, and Sierra Ancha, and Mazatzal Mountains. Much of the southern portion of the Agua Fria subbasin, the western portions of the Lower Salt and Middle Gila subbasins and the central portion of the San Carlos subbasin, which lay beyond the boundaries of the Tonto, are relatively flat with few springs. The percent of springs on lands within the boundary of the Tonto National Forest is greater in all subbasins than on lands outside the boundaries. The Tonto subbasin is almost entirely within the Tonto National Forest and the percent of springs within the Tonto reflects this fact.

Table 80 displays watershed area and numbers of stocktanks by subbasin both for the entire subbasin and for the portion of the subbasin within the Tonto National Forest. Stocktank data are derived from a GIS layer available from the Arizona Department of Water Resources.[4] Stocktanks are constructed primarily to provide water for livestock, but wildlife use is also often identified as a beneficial user of water. Water right filings with a prefix of "38" and "3R" were used to compare numbers of stocktanks on and off the Tonto National Forest. "38s" are "claims of water right for a stockpond and application for certification" and "3Rs" are applications for "Permit to Construct a Reservoir." Many "3Rs" are stocktanks. Water right claims for stocktanks are also made under other forms of applications available from Arizona Department of Water Resources (for example, "33s" and "36s") but identification of stocktanks using these prefixes was not considered necessary for purposes of comparing the percent of stocktanks on and off the Tonto National Forest. Land areas on Indian reservations were not considered for comparing the proportion of stocktanks on and off the Tonto National Forest because tribes are not required to submit applications for water rights, including stocktanks, on Reservation lands. The only exception was the Middle Gila watershed, which includes a number of water right claims on the San Carlos Reservation.

4 http://www.azwater.gov/azdwr/GIS/documents/SWRfilingActive.zip

Table 79. Number of springs on the Tonto National Forest (NF), by subbasin

Subbasin Number	Subbasin Name	Subbasin Area (square miles)	Tonto NF Area (square miles)	Tonto NF % of Watershed	No. of Springs in Watershed	No. of Springs in Tonto NF	% of Springs in Tonto NF
15040007	San Carlos	1,075	98	9.1%	87	41	47.1%
15050100	Middle Gila	3,326	260	7.8%	185	72	38.9%
15060103	Upper Salt	2,152	1,197	55.6%	416	328	78.8%
15060105	Tonto	1,048	1,038	99.0%	195	195	100.0%
15060106	Lower Salt	997	457	45.9%	95	92	96.8%
15060203	Lower Verde	1,965	1,297	66.0%	318	236	74.2%
15070102	Agua Fria	2,766	286	10.4%	391	60	15.3%
Not applicable	**Total**	**13,330**	**4,634**	**34.8%**	**1,687**	**1,024**	**60.7%**

Table 80. Number of stocktanks within subbasin context area

Subbasin Number	Subbasin Name	Subbasin Area (square miles)	Tonto NF Area* (square miles)	Tonto NF % of Watershed	No. of Stocktanks in Watershed	No. of Stocktanks Tonto NF	% of Stocktanks in Tonto NF
15040007	San Carlos	119	98	82.4%	82	50	61.0%
15050100	Middle Gila	3,326	260	7.8%	1,073	111	10.3%
15060103	Upper Salt	1,269	1,197	94.4%	460	432	93.9%
15060105	Tonto	1,048	1,038	99.0%	391	388	99.2%
15060106	Lower Salt	914	457	50.0%	41	32	78.0%
15060203	Lower Verde	1,921	1,297	67.5%	935	354	37.9%
15070102	Agua Fria	2,766	286	10.4%	1,028	122	11.9%
Not applicable	**Total**	**11,363**	**4,634**	**40.8%**	**4,010**	**1,489**	**37.1%**

* Excludes Indian Reservation lands except within the Middle Gila Watershed

The Arizona Department of Water Resources surface water rights database identifies 4,010 stocktanks within the subbasin context area, which include 1,489 stocktanks within the boundaries of the Tonto National Forest. The percentage of all stocktanks in the subbasin context area that are within the boundaries of the Tonto is similar to the percentage of the subbasin area within the national forest. Thirty-seven percent of stocktanks and 41 percent of subbasin area are within the boundaries of the Tonto National Forest.

Setting At and Below Planning Unit

Table 81 displays springs within watersheds, both within the entire watershed and within the Tonto National Forest portion of the watershed. Table 82 displays similar information for stocktanks. Figure 47 and figure 48 display the general locations of springs and stocktanks on the Tonto National Forest.

Springs

At the watershed level almost 50 percent of the watershed area is within the boundaries of the national forest yet 72 percent of the springs lie within the national forest boundary. Sixteen of the watersheds lie entirely within national forest boundaries and all springs in these watersheds lie within the national forest as well. In five of the watersheds, the Tonto is underrepresented in terms of the percent of springs within the national forest. In three of the five, less than 3 percent of the watershed lies within the national forest. The other two watersheds lie substantially within the boundaries of other national forests (the Coconino and Prescott National Forests). The percent of springs in the remaining 18 watersheds is greater within the Tonto National Forest boundary than the percent of watershed area within the Tonto National Forest boundary. The greater proportion may be due to the higher elevation and precipitation characteristics of lands within the Tonto National Forest.

Table 81. Number of springs on the Tonto National Forest (NF), by watershed

Subbasin and Watersheds	Watershed Number	Watershed Area (square miles)	Tonto NF Area (square miles)	Tonto NF (%)	No. of Springs in Watershed	No. of Springs in Tonto NF	%Springs in Tonto NF
Sevenmile Wash-Sycamore Creek	1504000702	252.91	58	23.1%	31	26	83.9%
Gilson Wash	1504000703	245.40	40	16.2%	34	15	44.1%
Dripping Springs Wash-Gila River	1505010001	392.72	5	1.3%	77	3	3.9%
Mineral Creek-Gila River	1505010002	258.92	55	21.3%	46	23	50.0%
Box O Wash-Gila River	1505010003	297.98	4	1.5%	12	1	8.3%
Upper Queen Creek	1505010004	143.31	143	99.4%	38	38	100.0%
Paisano Wash-Gila River	1505010007	373.57	2	0.4%	4		0.0%
Middle Queen Creek	150501000	381.28	49	12.9%	7	7	100.0%
Lower Queen Creek	1505010009	156.89	2	1.3%			
Sawmill Creek-Salt River	1506010302	266.75	17	6.2%	20	2	10.0%
Canyon Creek	1506010303	317.55	66	20.6%	30	15	50.0%
Cherry Creek	1506010304	278.15	265	95.3%	59	59	100.0%
Salt River Draw-Salt River	1506010305	236.30	132	55.8%	39	35	89.7%
Pinal Creek	1506010306	199.70	155	77.5%	67	59	88.1%
Pinto Creek	1506010307	185.99	186	100.0%	112	112	100.0%
Salome Creek	1506010308	118.70	119	100.0%	12	12	100.0%
Salt River-Theodore Roosevelt Lake	1506010309	259.15	259	100.0%	34	34	100.0%

Subbasin and Watersheds	Watershed Number	Watershed Area (square miles)	Tonto NF Area (square miles)	Tonto NF (%)	No. of Springs in Watershed	No. of Springs in Tonto NF	%Springs in Tonto NF
Tonto Subbasin							
Spring Creek	1506010501	146.73	147	100.0%	16	16	100.0%
Haigler Creek-Tonto Creek	1506010502	224.03	214	95.5%	17	17	100.0%
Rye Creek-Tonto Creek	1506010503	300.93	301	100.0%	76	76	100.0%
Gun Creek-Tonto Creek	1506010504	283.02	283	100.0%	65	65	100.0%
Tonto Creek-Theodore Roosevelt Lake	1506010505	93.06	93	100.0%	21	21	100.0%
Lower Salt Subbasin							
Salt River-Apache, Canyon, and Saguaro Lake	1506010601	388.43	388	100.0%	92	92	100.0%
Indian Bend Wash	1506010602	220.76	1	0.4%	3		0.0%
Salt River below Saguaro Lake	1506010603	431.31	68	15.7%			
Lower Verde Subbasin							
East Verde River	1506020302	331.27	317	95.8%	52	50	96.2%
Fossil Creek-Verde River	1506020303	299.17	62	20.8%	65	5	7.7%
Tangle Creek-Verde River	1506020304	277.56	278	100.0%	59	59	100.0%
Verde River-Horseshoe and Bartlett Reservoir	1506020305	300.23	300	100.0%	55	55	100.0%
Sycamore Creek	1506020306	192.56	190	98.7%	41	41	100.0%
Camp Creek-Verde River	1506020307	266.36	150	56.3%	26	26	100.0%
Agua Fria Subbasin							
Sycamore Creek-Agua Fria River	1507010204	365.85	105	28.6%	69	17	24.6%
Agua Fria River-Lake Pleasant	1507010205	371.82	11	3.1%	91	2	2.2%
Cave Creek-Arizona Canal Diversion Channel	1507010206	285.16	89	31.1%	24	20	83.3%
New River	1507010208	363.29	82	22.5%	25	21	84.0%

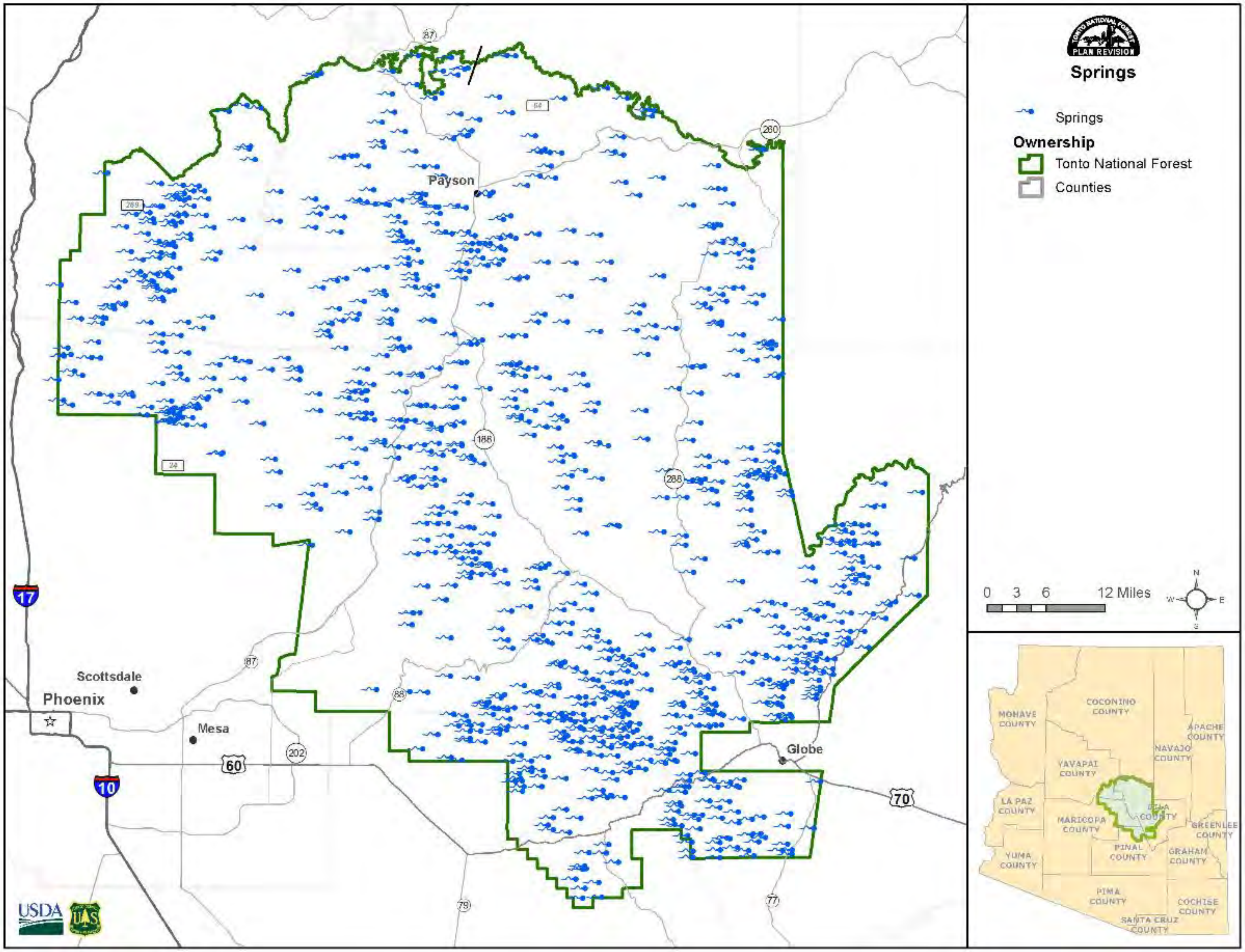


Figure 47. Location of springs on the Tonto National Forest

Stocktanks

With a few exceptions, the percent of stocktanks within the Tonto National Forest portion of each watershed is proportional to the percent of each watershed within the Tonto National Forest. Three watersheds have no stocktanks on the Tonto. The percent of the watershed area within the Tonto is less than 2 percent of these watersheds. There are two watersheds with fewer stocktanks than would be expected based on the percent of each watershed on the Tonto and five watersheds with more stocktanks than would be expected based on the percent of the each watershed.. On an overall basis, 55 percent of the watershed area and 51 percent of the stocktanks are within the Tonto National Forest boundary.

Table 82. Number of stocktanks on the Tonto National Forest, by watershed

Subbasin and Watersheds	Watershed Number	Watershed Area (square miles)	Tonto NF Area (square miles)	Tonto NF (%)	No. of Stocktanks in Watershed	No. of Stocktanks in Tonto NF	% Stocktanks in Tonto NF
San Carlos Subbasin							
Sevenmile Wash-Sycamore Creek	1504000702	58.4	58	100%	20	20	100%
Gilson Wash	1504000703	60.7	40	65%	62	30	48%
Middle Gila Subbasin							
Dripping Springs Wash-Gila River	1505010001	392.72	5	1%	112		0%
Mineral Creek-Gila River	1505010002	258.92	55	21%	168	54	32%
Box O Wash-Gila River	1505010003	297.98	4	1%	124	2	2%
Upper Queen Creek	1505010004	143.31	143	99%	51	49	96%
Paisano Wash-Gila River	1505010007	373.3	2	0%	112		0%
Middle Queen Creek	150501000	381.28	49	13%	187	6	3%
Lower Queen Creek	1505010009	118.61	2	2%	32		0%
Upper Salt Subbasin							
Sawmill Creek-Salt River	1506010302	16.5	17	100%	6	6	100%
Canyon Creek	1506010303	91.6	66	72%	48	35	73%
Cherry Creek	1506010304	265.0	265	100%	140	140	100%
Salt River Draw-Salt River	1506010305	131.9	132	100%	21	21	100%
Pinal Creek	1506010306	199.70	155	78%	108	93	86%
Pinto Creek	1506010307	185.99	186	100%	28	28	100%
Salome Creek	1506010308	118.70	119	100%	31	31	100%
Salt River-Theodore Roosevelt Lake	1506010309	259.15	259	100%	78	78	100%

Subbasin and Watersheds	Watershed Number	Watershed Area (square miles)	Tonto NF Area (square miles)	Tonto NF (%)	No. of Stocktanks in Watershed	No. of Stocktanks in Tonto NF	% Stocktanks in Tonto NF
Tonto Subbasin							
Spring Creek	1506010501	146.73	147	100%	63	63	100%
Haigler Creek-Tonto Creek	1506010502	224.03	214	95%	95	92	97%
Rye Creek-Tonto Creek	1506010503	300.85	301	100%	130	130	100%
Gun Creek-Tonto Creek	1506010504	283.02	283	100%	89	89	100%
Tonto Creek-Theodore Roosevelt Lake	1506010505	93.06	93	100%	14	14	100%
Lower Salt Subbasin							
Salt River-Apache, Canyon, and Saguaro Lake	1506010601	388.43	388	100%	23	23	100%
Indian Bend Wash	1506010602	198.5	1	0%	8	1	13%
Salt River below Saguaro Lake	1506010603	370.4	68	18%	10	8	80%
Lower Verde Subbasin							
East Verde River	1506020302	331.2	317	96%	150	139	93%
Fossil Creek-Verde River	1506020303	299.0	62	21%	266	44	17%
Tangle Creek-Verde River	1506020304	277.56	278	100%	88	88	100%
Verde River-Horseshoe and Bartlett Reservoir	1506020305	300.23	300	100%	36	36	100%
Sycamore Creek	1506020306	190.01	190	100%	27	27	100%
Camp Creek-Verde River	1506020307	225.35	150	67%	36	20	56%
Agua Fria Subbasin							
Sycamore Creek-Agua Fria River	1507010204	365.85	105	29%	226	56	25%
Agua Fria River-Lake Pleasant	1507010205	371.82	11	3%	184	2	1%
Cave Creek-Arizona Canal Diversion Channel	1507010206	285.16	89	31%	46	24	52%
New River	1507010208	363.29	82	22%	129	40	31%
(Not applicable)	**Total**	**8,368.38**	**4,634**	**55%**	**2,948**	**1,489**	**51%**

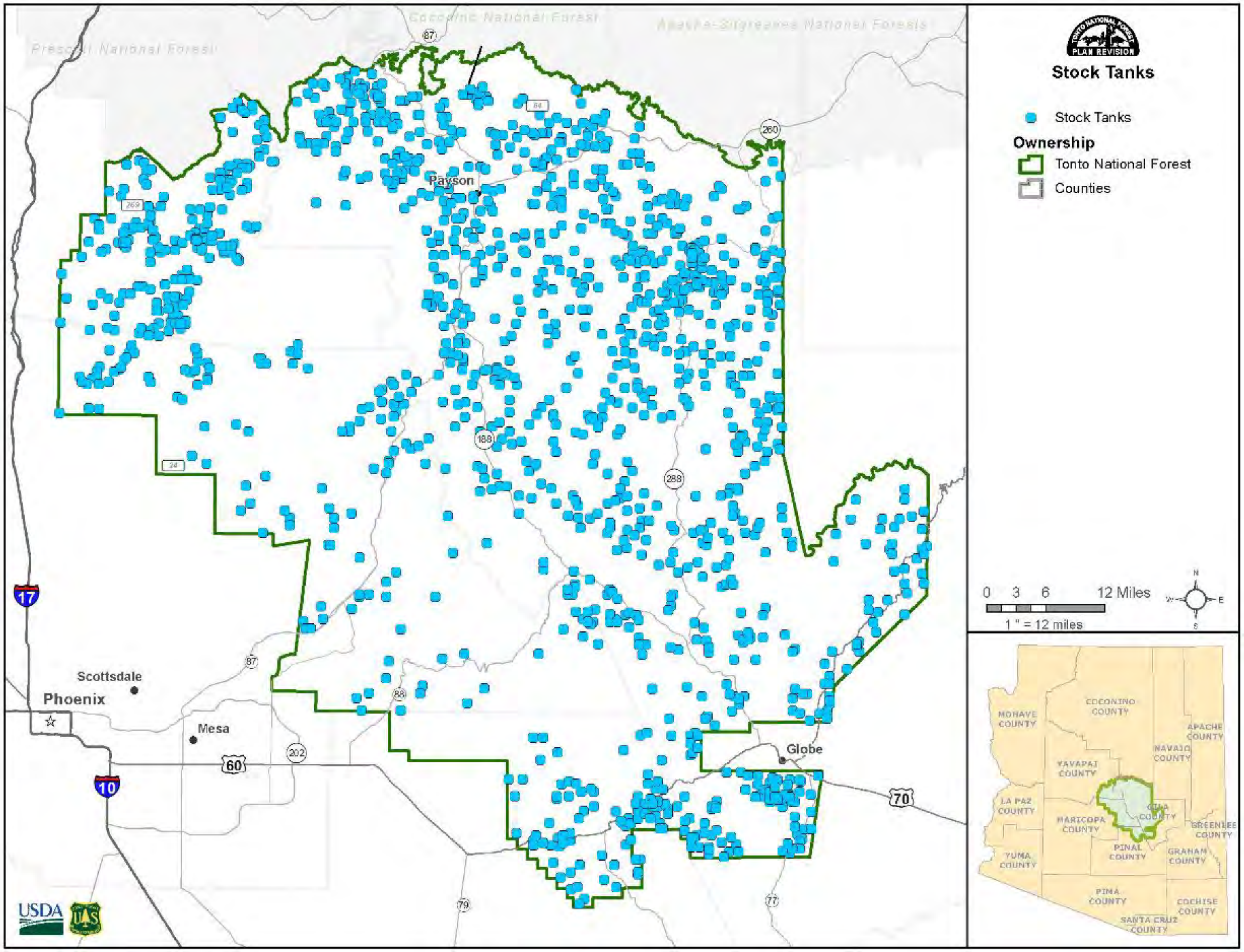


Figure 48. Locations of stocktanks on the Tonto National Forest

Current and Historical Conditions

Current Conditions

The Tonto National Forest water rights database identifies approximately 1,860 springs and seeps within the Tonto National Forest boundary. Approximately 760 of these springs have been inventoried as part of a water resources inventory being conducted on the Tonto. Approximately 360 (48 percent) of these springs have been developed for livestock use. Livestock and wildlife use occurs at many of the undeveloped springs as well. Approximately 75 (10 percent) of these springs have been fenced for various reasons and vegetation supported by these springs is protected from grazing. The number of developed and fenced springs that have not yet been inventoried is not known but may be similar to the percentages of springs that have been inventoried. A small number of springs have been developed for domestic uses. Spring developments (for both livestock and domestic use) capture and divert varying amounts of water discharged from the spring to troughs and tanks. The amount of water diverted from each spring is no longer available for sustaining the ecological values supported by the spring. Grazing of wetland and riparian vegetation supported by springs can damage the ecological values supported by springs if grazing exceeds levels needed to sustain the vegetation. Livestock trampling can also damage ecological values supported by springs. Where wetland and riparian vegetation supported by springs and seeps is fenced to exclude livestock, damage from grazing and trampling is reduced.

Fires can damage riparian vegetation supported by springs. Some riparian species such as sycamore and alder will resprout following fires. Herbaceous vegetation also often resprouts rapidly following fire. Other wetland and riparian plants can be killed by fire. Anecdotal reports of increased spring discharge and prolonged discharge from intermittent springs have occurred following wildfire (Neary et al. 2003).

Drought conditions can reduce recharge to aquifers that sustain discharge from springs and seeps. Reduced discharge or complete elimination of discharge due to drought conditions damages vegetation supported by springs and seeps.

Groundwater pumping can intercept groundwater moving through aquifers before the water discharges at springs and seeps. The effects of groundwater pumping on springs have been detected in the Sunflower Area along Sycamore Creek and in the Preacher Canyon area east of Payson. In Sycamore Creek an aquifer test of a well proposed as a water supply source for use in widening and realigning U.S. Highway 87 caused stream flow to decline from 90 gallons per minute to zero in six hours. Stream flow recovered to 61 gallons per minute 10 hours after the aquifer test was halted (Martin and Loomis 2007). Perennial stream flow in this reach of Sycamore Creek is maintained by discharge from springs just upstream of the flow measurement site monitored during the aquifer test. In the Preacher Canyon area, a water supply wellfield was proposed as a water source for widening and realigning U.S. Highway 260 east of Payson. Pumping of a four-well wellfield stopped discharge from one spring and appeared to result in declining flow in a second spring and in Little Green Valley Creek; however, runoff from a storm made the results at the second two sites inconclusive (Agra 1998).

Degraded upland watershed conditions from poor watershed management practices can reduce rainfall and snowmelt infiltration into the ground and reduce recharge to aquifers. Reduced recharge can reduce discharge from springs and seeps and their ecological sustainability functions.

The Tonto National Forest water rights database identifies 1,405 stocktanks on Tonto National Forest System lands. These include 69 road, wing, and trick tanks in addition to traditional tanks that capture water flowing from small upland watersheds. Stock tanks help distribute livestock use more evenly across the landscape so that grazing pressure at traditional water sources is reduced. Stocktanks also provide water for a variety of wildlife species. Livestock tend to congregate close to stock tanks and reduce soil and vegetative condition towards unsatisfactory in close proximity to the tanks. The aerial extent of these conditions is small, generally not more than a few acres around each tank. Stocktanks are vulnerable to drought conditions and are less reliable water sources than perennial streams, springs, and seeps.

Historical Conditions

Springs were used by Native Americans for domestic water and potentially for irrigation. The scale of disturbance was probably less than current conditions where some springs can be diverted and piped for many miles. Native Americans did not manage livestock and would not have developed springs for livestock use. Springs would not have been affected by pumping, mining, and recreational uses.

Stocktanks are a recent development and did not exist prior to arrival of non-indigenous peoples. The vast majority of stocktanks were constructed during the mid to late 1900s.

Reference Conditions

Limited information is available about the natural range of variation of springs and seeps. Stocktanks are a recent development and are not considered in terms of natural range of variation. Variability in discharge of springs and seeps would have occurred during wet periods and drought periods and possibly following fires. To assess the reference conditions of springs and seeps, the alternatives to natural range of variation were used that consider the representativeness and redundancy of these features within the national forest and context area. Representativeness and redundancy are described under the “Watershed Extent and Perennial Streams” discussion. Representativeness and redundancy characteristics for springs and seeps in subbasins and watersheds are displayed in table 83 and table 84.

Table 83 displays that springs and seeps on the Tonto National Forest are overrepresented on five of the seven subbasins that contain a portion of the Tonto as well as on the Tonto as a whole. This may be due to the mountainous character of much of the Tonto National Forest where greater precipitation and favorable geologic conditions may favor the presence of springs and seeps on the Tonto as compared to conditions outside the Tonto. The only exception would be the Upper Salt subbasin where mountainous conditions on both the White Mountain and San Carlos Apache Reservation portions of the subbasin would be similar to conditions on the Tonto National Forest. It may be that fewer springs have been inventoried on the reservations than on the Tonto. The number of springs and seeps within the Tonto National Forest portion of two of the subbasins is proportional to the total number of springs within the subbasins. The Tonto subbasin lies almost entirely within the Tonto National Forest and all the springs in the subbasin lie within its boundary. The characteristics of the Verde subbasin are similar both on and off the Tonto as are the number of springs and seeps which results in a proportional rating.

Table 83. Representativeness of springs and seeps on the Tonto National Forest (NF) by subbasin

Subbasin	Number	Subbasin area (square miles)	Tonto NF area in Subbasin (square miles)	Tonto NF area in Subbasin (%)	No. of Springs in Subbasin	No. of Springs in Tonto NF	Springs % of Tonto NF	Representative-ness Index	Representative-ness Rating
San Carlos	15040007	1,075	98	9.1%	87	41	47.1%	5.16	Over
Middle Gila	15050100	3,326	260	7.8%	185	72	38.9%	4.98	Over
Upper Salt	15060103	2,152	1,197	55.6%	416	328	78.8%	1.42	Over
Tonto	15060105	1,048	1,038	99.0%	195	195	100.0%	1.01	Proportional
Lower Salt	15060106	997	457	45.9%	95	92	96.8%	2.11	Over
Lower Verde	15060203	1,965	1,297	66.0%	318	236	74.2%	1.12	Proportional
Agua Fria	15070102	2,766	286	10.4%	391	60	15.3%	1.48	Over
Not applicable	**Totals**	**13,330**	**4,634**	**34.8%**	**1,687**	**1,024**	**60.7%**	**1.75**	**Over**

Table 84. Representativeness of springs and seeps on the Tonto National Forest (NF) by watershed

Subbasin and Watersheds	Watershed area (square miles)	Tonto NF Watershed Area (square miles)	Tonto NF Watershed Area (%)	No. of Springs in Subbasin	No. of Springs in Tonto NF	Springs % of Tonto NF	Representative-ness Index	Representative-ness Rating
San Carlos Subbasin								
Sevenmile Wash-Sycamore Creek	253	58	23.1%	31	26	83.9%	3.63	Over
Gilson Wash	245	40	16.2%	34	15	44.1%	2.73	Over
Middle Gila Subbasin								
Dripping Springs Wash-Gila River	393	5	1.3%	77	3	3.9%	3.11	Over
Mineral Creek-Gila River	259	55	21.3%	46	23	50.0%	2.35	Over
Box O Wash-Gila River	298	4	1.5%	12	1	8.3%	5.65	Over
Upper Queen Creek	143	143	99.4%	38	38	100.0%	1.01	Proportional
Paisano Wash-Gila River	374	2	0.4%	4		0.0%	0.00	Under
Middle Queen Creek	381	49	12.9%	7	7	100.0%	7.74	Over

Subbasin and Watersheds	Watershed area (square miles)	Tonto NF Watershed Area (square miles)	Tonto NF Watershed Area (%)	No. of Springs in Subbasin	No. of Springs in Tonto NF	Springs % of Tonto NF	Representative-ness Index	Representative-ness Rating
Lower Queen Creek	157	2	1.3%				0.00	
Upper Salt Subbasin								
Sawmill Creek-Salt River	267	17	6.2%	20	2	10.0%	1.62	Over
Canyon Creek	318	66	20.6%	30	15	50.0%	2.42	Over
Cherry Creek	278	265	95.3%	59	59	100.0%	1.05	Proportional
Salt River Draw-Salt River	236	132	55.8%	39	35	89.7%	1.61	Over
Pinal Creek	200	155	77.5%	67	59	88.1%	1.14	Proportional
Pinto Creek	186	186	100%	112	112	100.0%	1.00	Proportional
Salome Creek	119	119	100%	12	12	100.0%	1.00	Proportional
Salt River-Theodore Roosevelt Lake	259	259	100%	34	34	100.0%	1.00	Proportional
Tonto Subbasin								
Spring Creek	147	147	100%	16	16	100.0%	1.00	Proportional
Haigler Creek-Tonto Creek	224	214	95.5%	17	17	100.0%	1.05	Proportional
Rye Creek-Tonto Creek	301	301	100%	76	76	100.0%	1.00	Proportional
Gun Creek-Tonto Creek	283	283	100%	65	65	100.0%	1.00	Proportional
Tonto Creek-Theodore Roosevelt Lake	93	93	100%	21	21	100.0%	1.00	Proportional
Lower Salt Subbasin								
Salt River-Apache, Canyon, and Saguaro Lake	388	388	100%	92	92	100.0%	1.00	Proportional
Indian Bend Wash	221	1	0.4%	3		0.0%	0.00	Under
Salt River below Saguaro Lake	431	68	15.7%				0.00	

Subbasin and Watersheds	Watershed area (square miles)	Tonto NF Watershed Area (square miles)	Tonto NF Watershed Area (%)	No. of Springs in Subbasin	No. of Springs in Tonto NF	Springs % of Tonto NF	Representative-ness Index	Representative-ness Rating
Lower Verde Subbasin								
East Verde River	331	317	95.8%	52	50	96.2%	1.00	Proportional
Fossil Creek-Verde River	299	62	20.8%	65	5	7.7%	0.37	Under
Tangle Creek-Verde River	278	278	100%	59	59	100.0%	1.00	Proportional
Verde River-Horseshoe and Bartlett Reservoir	300	300	100%	55	55	100.0%	1.00	Proportional
Sycamore Creek	193	190	98.7%	41	41	100.0%	1.01	Proportional
Camp Creek-Verde River	266	150	56.3%	26	26	100.0%	1.78	Over
Agua Fria Subbasin								
Sycamore Creek-Agua Fria River	366	105	28.6%	69	17	24.6%	0.86	Proportional
Agua Fria River-Lake Pleasant	372	11	3.1%	91	2	2.2%	0.72	Under
Cave Creek-Arizona Canal Diversion Channel	285	89	31.1%	24	20	83.3%	2.68	Over
New River	363	82	22.5%	25	21	84.0%	3.74	Over
Total	**9,507**	**4,634**	**48.7%**	**1,419**	**1,024**	**72.2%**	**1.48**	**Over**

Table 85. Redundancy assessment of springs and seeps within subbasins of the Tonto National Forest (NF)

Subbasin and Watersheds	Watershed Number	Tonto NF Springs and Seeps	Even Distribution* (miles)	Deviation (miles)	Proportional Deviation	Redundancy
San Carlos Subbasin						
Sevenmile Wash-Sycamore Creek	1504000702	26	21	-5.00	-0.25	moderate
Gilson Wash	1504000703	15	21	6.00	0.29	moderate
Middle Gila Subbasin						
Dripping Springs Wash-Gila River	1505010001	3	10	7.00	0.70	low
Mineral Creek-Gila River	1505010002	23	10	-13.00	-1.30	low
Box O Wash-Gila River	1505010003	1	10	9.00	0.90	low
Upper Queen Creek	1505010004	38	10	-28.00	-2.80	low
Paisano Wash-Gila River	1505010007		10	10.00	1.00	low
Middle Queen Creek	150501000	7	10	3.00	0.30	low
Lower Queen Creek	1505010009		10	10.00	1.00	low
Upper Salt Subbasin						
Sawmill Creek-Salt River	1506010302	2	41	39.00	0.95	moderate
Canyon Creek	1506010303	15	41	26.00	0.63	moderate
Cherry Creek	1506010304	59	41	-18.00	-0.44	moderate
Salt River Draw-Salt River	1506010305	35	41	6.00	0.15	moderate
Pinal Creek	1506010306	59	41	-18.00	-0.44	moderate
Pinto Creek	1506010307	112	41	-71.00	-1.73	moderate
Salome Creek	1506010308	12	41	29.00	0.71	moderate
Salt River-Theodore Roosevelt Lake	1506010309	34	41	7.00	0.17	moderate
Tonto Subbasin						
Spring Creek	1506010501	16	39	23.00	0.59	moderate
Haigler Creek-Tonto Creek	1506010502	17	39	22.00	0.56	moderate
Rye Creek-Tonto Creek	1506010503	76	39	-37.00	-0.95	moderate
Gun Creek-Tonto Creek	1506010504	65	39	-26.00	-0.67	moderate
Tonto Creek-Theodore Roosevelt Lake	1506010505	21	39	18.00	0.46	moderate

Subbasin and Watersheds	Watershed Number	Tonto NF Springs and Seeps	Even Distribution* (miles)	Deviation (miles)	Proportional Deviation	Redundancy
Lower Salt Subbasin						
Salt River-Apache, Canyon, and Saguaro Lake	1506010601	92	31	-61.00	-1.97	low
Indian Bend Wash	1506010602		31	31.00	1.00	low
Salt River below Saguaro Lake	1506010603		31	31.00	1.00	low
Lower Verde Subbasin						
East Verde River	1506020302	50	39	-11.00	-0.28	moderate
Fossil Creek-Verde River	1506020303	5	39	34.00	0.87	moderate
Tangle Creek-Verde River	1506020304	59	39	-20.00	-0.51	moderate
Verde River-Horseshoe and Bartlett Reservoir	1506020305	55	39	-16.00	-0.41	moderate
Sycamore Creek	1506020306	41	39	-2.00	-0.05	moderate
Camp Creek-Verde River	1506020307	26	39	13.00	0.33	moderate
Agua Fria Subbasin						
Sycamore Creek-Agua Fria River	1507010204	17	15	-2.00	-0.13	moderate
Agua Fria River-Lake Pleasant	1507010205	2	15	13.00	0.87	moderate
Cave Creek-Arizona Canal Diversion Channel	1507010206	20	15	-5.00	-0.33	moderate
New River	1507010208	21	15	-6.00	-0.40	moderate

* Even distribution derived by dividing the number of springs within a subbasin by the number of watersheds within each subbasin.

Trends and Projections

Trends for springs and seeps are somewhat comparable to those for perennial streams. Trends are variable depending on local conditions. Resources supported by springs and seeps are generally resilient as long as water continues to discharge from the source. Springs and seeps are attractive for livestock, wildlife, and human use and require management to prevent them from being degraded by excessive use. Climate change may result in drier conditions and more erratic rainfall patterns that may reduce aquifer recharge and consequently discharge from springs and seeps.

Discharge from the complex of springs creating the Fossil Springs area was diverted for power production at the Irving and Childs hydroelectric plants until 2005 when these plants were decommissioned and full flows were restored to Fossil Creek. Restoring full flows has allowed the travertine laden water discharging from the springs to rebuild travertine structures historically existing in the creek. This process is continuing.

Groundwater pumping from developed areas, communities, and mines within the external boundaries of the Tonto National Forest has the potential to impact water table elevations and potentially reduce discharge from springs and seeps. Fencing of springs and seeps that support groundwater-dependent ecosystems has the potential to improve the condition of these areas. Replacement of spring developments with eco-friendly spring boxes that ensure some water remains to support groundwater-dependent ecosystems also has the potential to maintain or improve the condition of these resources.

Stocktanks may become a less reliable source of water with the drier and more erratic rainfall patterns anticipated with climate change. Higher intensity storms may result in increased maintenance requirements for stocktanks.

Water Quality

The primary source of pollution from National Forest System lands are nonpoint source pollutants. Nonpoint source pollutants are derived from diffuse overland sources, in contrast to point sources of pollutants which discharge from identifiable outlets such as pipes or ditches from industrial or sewage treatment sources. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground that erodes and transports natural and human-made pollutants and eventually deposits them into streams, lakes, rivers, wetlands, and groundwater (ADEQ 2013). Activities such as agriculture, construction, forestry, and mining are sources of nonpoint pollutants. Nonpoint source pollution remains the Nation’s largest source of water quality problems and is the main reason that approximately 40 percent of the surveyed streams and rivers in the state do not attain water quality standards (ADEQ 2013). Activities generating nonpoint source pollutants on the Tonto National Forest include past and present mining activities, livestock grazing, roads, timber and fuelwood harvesting, impoundments, recreational uses, and ground disturbance created by off-highway-vehicle use. Natural and unknown sources of pollutants also contribute to nonpoint source pollution on the Tonto. Primary nonpoint source pollutants causing impairment to surface waters within the Tonto National Forest include:

- nutrients or related parameters (nitrogen, phosphorous, low dissolved oxygen),
- *E. coli* bacteria,
- metals (copper, lead, thallium, and mercury in fish tissue),
- selenium,
- arsenic, and
- suspended sediment.

Activities that reduce stream shading can also cause violations of water quality standards for stream temperature (particularly in cold-water, high-elevation streams) and dissolved oxygen.

Water quality is assessed by comparing existing conditions with water quality standards established for designated uses identified by the State under the authority of the Clean Water Act. The Arizona Department of Environmental Quality is the regulating authority for water quality in Arizona. The Department identifies designated uses for individual stream reaches and waterbodies across the state that water quality standards are intended to protect. Designated uses include (ADEQ 2014):

- Aquatic and wildlife habitat
    - Cold water communities (above 5,000 feet elevation)
    - Warm water communities (below 5,000 feet elevation)
    - Ephemeral (channel dry except in direct response to precipitation)
    - Effluent-dependent water (ephemeral conditions except for treated effluent
- Full body contact (swimming) or partial body contact (incidental contact only)
- Domestic water sources (drinking water)
- Fish consumption (human consumption of aquatic life)
- Agricultural irrigation
- Agricultural livestock watering

Individual waterbodies are categorized based on how well they attain the water quality standards for the designated uses identified for the waterbody. Arizona Department of Environmental Quality prepares an assessment of the quality of the state's surface waters every two years in a report prepared to comply with the Clean Water Act (known as the 305(b) report). They also identify waterbodies that do not meet water quality standards (referred to as "impaired waterbodies") in a report known as the 303(d) listing report. These two reports are combined into a document known as the Status of Water Quality in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report. Arizona Department of Environmental Quality has issued the 2012/2014 assessment report (ADEQ 2014) and this was used for assessing the current water quality condition of streams and lakes on the Tonto National Forest. Assessed waterbodies are placed in specific water quality categories that are described below.

- **Category 1: Attaining All Uses** – There is sufficient data to determine all designated uses are supported.
- **Category 2: Attaining Some Uses** – At least one designated use assessed as "attaining," and no designated uses were not attaining or impaired.
- **Category 3: Inconclusive or Not Assessed** – Insufficient samples or core parameters to assess any designated uses.
- **Category 4: Not attaining** – One or more designated use is not attaining but a total maximum daily load (TMDL) analysis is not required.
- **Category 5: Impaired** – One or more designated uses is not attaining, and a total maximum daily load needs to be developed or revised.

Figure 49 displays the water quality status of streams, rivers and lakes on the Tonto National Forest based on the 2012/2014 Water Quality Assessment Report.

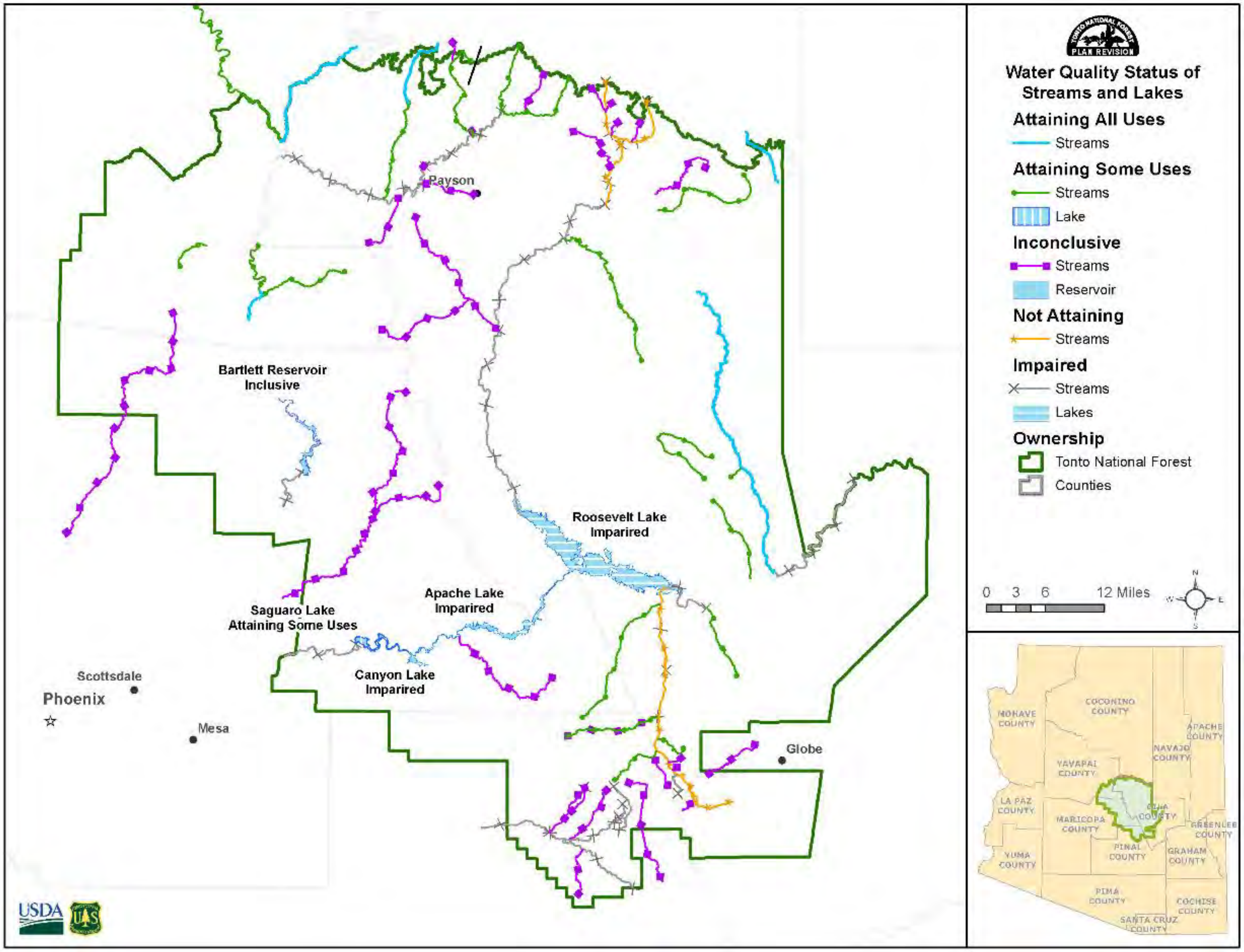


Figure 49. Water quality status of streams and lakes on the Tonto National Forest (note: Bartlett Reservoir should say "Bartlett Lake Inconclusive")

A total maximum daily load analysis identifies the amount "of a water quality parameter that can be carried by a surface waterbody, on a daily basis, without causing an exceedance of surface water quality standards" (ADEQ 2014).[5] A total maximum daily load is intended to help an impaired stream or lake meet its water quality standards and support its designated uses. Arizona Department of Environmental Quality is responsible for preparing TMDL analyses, which include measures designed to reduce the pollutants causing impairment to levels where water quality standards can be met. Implementation of mitigation measures identified in a TMDL is the responsibility of the landowner or manager; however, Arizona Department of Environmental Quality administers a water quality improvement grant program to assist in accomplishment.

Arizona water quality standards apply to surface water in the state. Surface waters include lakes, reservoirs, natural ponds, rivers, streams (including ephemeral, intermittent, and perennial streams), and wetlands. Water quality standards are specifically identified for many of the perennial waterbodies in the state. Specifically identified waterbodies and their protected uses can be found in Appendix B of the State's water quality standards (Arizona Administrative Code 2014). Water quality standards also apply to ephemeral, intermittent, and perennial surface waters and tributaries to surface waters that are not specifically listed by name in Appendix B. Applicable standards to waterbodies that are tributary to a listed waterbody are found in Rule 18-11-104 of the Arizona Administrative Code and include:

1. the aquatic and wildlife (ephemeral) and partial-body contact standards apply to an unlisted tributary that is an ephemeral water,
2. the aquatic and wildlife (cold water), full-body contact, and fish consumption standards apply to an unlisted tributary that is perennial or intermittent surface water and is above 5,000 feet in elevation, and
3. the aquatic and wildlife (warm water), full-body contact, and fish consumption standards apply to an unlisted tributary that is perennial or intermittent surface water and is below 5,000 feet in elevation.

The State has also developed standards for effluent-dependent water and surface waters designated as an "Outstanding Arizona Water" (R18-11-112 and 113 of the Arizona Administrative Code 2014). An effluent-dependent water consists of a point source discharge of wastewater to surface water that would be an ephemeral water in the absence of the discharge. Two streams that flow partly across the Tonto National Forest are designated as effluent-dependent waters: Queen Creek from the outfall of the Town of Superior Waste Water Treatment Plant to the confluence with Potts Canyon and American Gulch from the outfall of the Northern Gila County Waste Water Treatment Plant (Payson) to the confluence with the East Verde River.

An "Outstanding Arizona Water" is surface water classified as an outstanding state resource water by the Director of Arizona Department of Environmental Quality. Fossil Springs and Fossil Creek are the only designated outstanding Arizona waters within the Tonto National Forest. Fossil Creek forms part of the boundary between the Tonto and Coconino National Forests.

Arizona Department of Environmental Quality considers waters identified as impaired or not attaining as those with the most severe water quality problems. Permit requirements for discharge into these waters are more restrictive than waters that are not impaired and Arizona Department of Environmental Quality and the Tonto National Forest must ensure new discharges or modifications will not further degrade water quality.

[5] http://www.azdeq.gov/environ/water/assessment/tmdl.html

The Southwestern Region of the Forest Service and the Arizona Department of Environmental Quality have entered into a memorandum of understanding (FS Agreement No. 15-MU-11031600-001) that “Designates the U.S. Forest Service as the designated Planning and Management Agency for National Forest System lands within the context of the Arizona Water Quality Management Program” (USDA Forest Service 2014). The Forest Service agrees in this memorandum to include site-specific best management practices for all ground-disturbing projects on National Forest System lands. Best management practices are methods, measures, or practices to prevent or reduce water pollution, including, but not limited to, structural and nonstructural controls, and operation and maintenance procedures. These practices are usually applied as a system of practices rather than a single practice and are selected on the basis of site-specific conditions that reflect natural background conditions and political, social, economic, and technical feasibility. Best management practices can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters (USDA Forest Service 2012).

Section 310 of the Clean Water Act directed states to identify best management practices for categories of nonpoint source problems, and develop programs to implement best management practices. The Arizona Department of Environmental Quality developed a best management practices manual of watershed remediation methods in partnership with the University of Arizona Non-point Education for Municipal Officials program in 2010. The manual is available online.[6] Implementation and monitoring of best management practices is the fundamental basis of the Forest Service water quality management program to protect, restore, or mitigate water quality impacts from activities on National Forest System lands (USDA Forest Service 2012). Forest Service personnel have developed a national best management practices program that includes a core set of best management practices to control nonpoint source pollution on all National Forest System lands. The document containing the core set of best management practices is available online.[7] These and other sources of best management practices are implemented on the Tonto National Forest to control nonpoint sources of pollution.

Groundwater quality standards: Surface water quality standards do not apply to groundwater. Arizona has adopted aquifer water quality standards that reflect the safe drinking water standards established for public water systems and surface water standards for the domestic water source designated use.

Setting above Planning Unit

Table 86 displays status of assessed surface waters by subbasin context area. Table 87 displays the percent of assessed streams within the Tonto National Forest included in each assessment category. Sixty-five percent of the assessed stream miles within the context area lie within the Tonto National Forest, which is greater than the 52 percent of perennial stream miles within the Tonto boundary. Table 87 shows a greater percentage of streams assessed as categories 1 (attaining all uses), 4 (impaired or threatened for at least one use but a total maximum daily load is not necessary) and 5 (impaired or threatened for one or more designated uses and a total maximum daily load is necessary) lie within the Tonto National Forest than the percent of assessed streams within the Tonto (65 percent).

[6] http://issuu.com/aznemo/docs/bmp?e=2477955/2609255

[7] http://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf.

Table 86. Water quality status of streams within subbasins

Subbasin	Assessed Stream Miles in Watershed	Portion of Assessed Stream Miles in Tonto NF	% Tonto NF	Cat. 1 WS	Cat. 1 TNF	Cat. 2 WS	Cat. 2 TNF	Cat. 3 WS	Cat. 3 TNF	Cat. 4 WS	Cat. 4 TNF	Cat. 5 WS	Cat. 5 TNF
San Carlos	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Gila	114.3	66	58	0	0	0	0	48.7	31.2	0	0	65.5	34.8
Upper Salt	200.3	184.4	92	48	46.8	61.9	61.9	24.4	18.4	36	36	30.1	21.3
Tonto	161.9	161.7	100	0	0	35.8	35.8	54.2	54	24.6	24.6	47.3	47.3
Lower Salt	37.8	26	69	0	0	0	0	27.7	16.4	0	0	10.1	9.6
Lower Verde	284	207.3	73	29.6	19.5	136.6	74.5	66.1	61.6	0	0	51.7	51.7
Agua Fria	215.8	17.6	8	0	0	23	0	162.7	17.6	21	0	9.1	0
Total	**1,014.1**	**663**	**65**	**77.6**	**66.3**	**257.3**	**172.2**	**383.8**	**199.2**	**81.6**	**60.6**	**213.8**	**164.7**

WS = Watershed, means assessed stream miles within the entire watershed. TNF=Tonto National Forest and means portion of assessed stream miles within the national forest

Category (Cat.) 1: Attaining All Uses – There is sufficient data to determine that all designated uses are supported.

Category 2: Attaining Some Uses – At least one designated use assessed as “attaining,” and no designated uses were not attaining or impaired.

Category 3: Inconclusive or Not Assessed – Insufficient samples or core parameters to assess any designated uses.

Category 4: Not attaining – One or more designated use is not attaining but a total maximum daily load (TMDL) analysis is not required.

Category 5: Impaired – One or more designated uses is not attaining, and a TMDL needs to be developed or revised.

Table 87. Percent of subbasin streams within Tonto National Forest (NF)

Assessment Category	Assessed Streams within Subbasin	Assessed Streams within Tonto NF	Tonto NF Streams within Assessment Category
1	77.6 miles	66.3 miles	85 %
2	257.3 miles	172.2 miles	67 %
3	383.8 miles	199.2 miles	52 %
4	81.6 miles	60.6 miles	74 %
5	213.8 miles	164.7 miles	77 %
Total	**1,014.1 miles**	**663.0 miles**	**65 %**

The percent of streams on the Tonto National Forest assessed as category 2 (attaining some uses) is similar to the percent of assessed streams within the Tonto. The percent of streams assessed as category 3 (insufficient data) is less than the percent of assessed streams within the Tonto. Water quality on Indian Reservation lands within the subbasins is not assessed by Arizona Department of Environmental Quality. Substantial portions of the San Carlos and Upper Salt subbasins lie within the San Carlos and Fort Apache Indian Reservations, respectively.

Setting At and Below Planning Unit

Water quality of surface waters has been assessed on 663 miles of perennial, intermittent, and ephemeral streams on the Tonto National Forest. Water quality has also been assessed on all six reservoirs on the Tonto. Table 89 identifies the water quality status of specific streams and rivers in the Tonto National Forest that have been assessed by Arizona Department of Environmental Quality for the Draft 2012/2014 305(b) report. Table 90 identifies the water quality status of lakes on the Tonto that were also assessed for the draft report. All major lakes, except Horseshoe Reservoir, were assessed for the 2012/2014 report. Horseshoe Reservoir was assessed in the 2010 report and is included in table 90. Arizona Department of Environmental Quality assessed 513 miles of streams and rivers and 6 lakes on the Tonto National Forest in the 2010 assessment report. The percent of streams and rivers in the assessment categories for each assessment period is displayed in table 88.

Table 88. Percent of streams and rivers in each assessment category

Assessment Category	Percent of Stream Miles 2010	Percent of Stream Miles 2012 / 2014
Attaining all Uses	4	10
Attaining Some Uses	28	26
Inconclusive	36	30
Not Attaining	5	3
Not Attaining/Impaired *	6	6
Impaired	21	25

* These streams have a total maximum daily load completed for one constituent but are impaired for other constituents.

These data show an increase in both the percent of stream miles assessed as attaining all uses and the percent of stream miles assessed as impaired from the 2010 to 2012/14 reports. Much of the increase in stream miles rated as impaired is from designating 62 miles of Tonto Creek as impaired due to mercury in fish tissue. Three lakes were identified as impaired in the both the 2010 and 2012/14 assessment reports. Apache and Canyon Lakes were impaired for low dissolved oxygen and Roosevelt Lake was impaired for mercury in fish tissue. The assessment category for Bartlett Lake declined from 2 (attaining some uses) in the 2010 assessment to 3 (inconclusive) in the 2012 assessment. A fish consumption advisory due to mercury contamination in fish tissue was issued for Bartlett Lake in 2015. Horseshoe Reservoir was assessed as 3 (inconclusive) in the 2010 report. No further monitoring was recommended for Horseshoe Reservoir in the 2010 report because the lake is dry for extended periods of time which makes seasonal sampling difficult (ADEQ 2014).

Table 89. Water quality condition of assessed waters on the Tonto National Forest

Waterbody	Reach Name	Reach Number	Miles Assessed	Assessed Category	Parameters with Exceedances*	Cause of Impairment	Impaired Uses
Middle Gila Subbasin							
Arnett Creek	Headwaters - Queen Creek	15050100-1818	11.1	5	None	Copper	Aww
Queen Creek	Headwaters - Superior Mining Div. Outfall	15050100-014A	8.8	5	None	Lead, copper, selenium	PBC, AGL, A&Ww
Queen Creek	Potts Canyon - Whitlow Canyon	15050100-014C	8	5	None	Copper	A&Ww
Queen Creek	Superior Mining WWTP - Potts Canyon	15050100-014B	5.9	5	None	Copper	A&Wedw
Trib (UQ2) to Queen Creek	Headwaters - Queen Creek	15050100-1000	0.5	5	None	Copper	A&We
Trib (UQ3) to Queen Creek	Headwaters (Near Kings Crown Pk) - Queen Ck	15050100-1843	1.7	5	None	Copper	A&We
Trib (UQE) to Queen Creek	Headwaters - Queen Creek	15050100-991	2	5	None	Copper	A&We
Devils Canyon	Headwaters - Mineral Creek	15050100-1662	12.9	3	Copper	None	None
Peachville Wash	Headwaters - Fortuna Wash	15050100-1846	2.1	3	None	None	None
Potts Canyon	Headwaters - Queen Creek	15050100-1856	5.6	3	None	None	None
Silver King Wash	Headwaters - Queen Creek	15050100-2085	5.1	3	Arsenic, copper, lead	None	None
Telegraph Canyon	Headwaters - Arnett Creek	15050100-1819	6.1	3	Lead	None	None
Trib to Dry Mineral Creek	Headwaters - Dry Mineral Creek	15050100-212	1.4	3	None	None	None
Whitford Canyon	Wood Camp Canyon - Potts Canyon	15050100-1860	4.1	3	Lead	None	None
Upper Salt Subbasin							
Devils Chasm Creek	Trib at 334846/110523 - Cherry Creek	15060103-801B	1.6	2	E. coli	None	None
Canyon Creek	Headwaters - White Mtn Apache	15060103-014	8.6	1	None	None	None
Cherry Creek	Trib at 340509/110560 - Salt River	15060103-015B	40.9	1	None	None	None
Salt River	Canyon Creek - Cherry Creek	15060103-007	19.6	5	None	Selenium	A&Ww
Coon Creek	Trib at 334642/110542 - Salt River	15060103-039B	10.1	2	Dissolved oxygen, SSC	None	None
Bloody Tanks Wash	Schultze Ranch - Miami Wash	15060103-034B	6.645	3	Copper	None	None
Pinal Creek	Lower Pinal Creek WTP discharge - Salt River	15060103-280D	6.4	2	Nitrogen	None	None
Salt River	Pinal Creek - Roosevelt lake	15060103-004	7.5	5	None	*E. coli,* Phosphorous, nitrogen, SSC	FBC, A&Ww

Waterbody	Reach Name	Reach Number	Miles Assessed	Assessed Category	Parameters with Exceedances*	Cause of Impairment	Impaired Uses
Workman Creek	Headwaters - Reynolds Creek	15060103-195A	7.1	2	Dissolved oxygen	None	None
Reynolds Creek	Headwaters - Workman Creek	15060103-202	6.8	2	pH, selenium	None	None
Five Point Mountain Tributary	Headwaters - Pinto Creek	15060103-885	2.9	5	None	Dissolved copper	A&We[2]
Pinto Creek	West Fork Pinto Creek - Roosevelt lake	15060103-018C	18.4	4A/5	None	Selenium (5), copper(4A)	A&Ww
Gibson Mine Tributary	Headwaters - Pinto Creek	15060103-887	1.1	4A	None	Copper (4A)	A&Ww
Pinto Creek	Headwaters - Trib at 331927/1105456	15060103-018A	2.5	4A	None	Copper	A&Wc not attaining
Pinto Creek	Trib at 331927/110545 - West Fork Pinto Creek	15060103-018B	15.3	4A	None	Copper	A&Ww
Miller Springs Gulch	Headwaters - Pinto Creek	15060103-892	1.6	3	None	None	None
Cottonwood Gulch	Headwaters - Pinto Creek	15060103-891	1.9	3	None	None	None
Powers Gulch	Headwaters - Haunted Canyon	15060103-884	3.8	3	copper	None	None
Haunted Canyon	Headwaters - Pinto Creek	15060103-879	6.8	2	None	None	None
Gold Gulch	Headwaters - Pinto Creek	15060103-894	3.3	2	None	None	None
West Fork Pinto Creek	Headwaters - Pinto Creek	15060103-066	11.6	3	Nitrogen, bottom deposits	None	None
Campaign Creek	Headwaters - Pinto Creek	15060103-037	16.579	2	None	None	None
Tonto Subbasin							
Trib to Christopher Creek	Headwaters - Christopher Creek	15060105-362	2.4	3	None	None	None
Christopher Creek	Headwaters - Tonto Creek	15060105-353	8	4A/5	None	Phosphorous (5), *E. coli*(4A)	A&Wc
Tonto Creek (TON)	Headwaters - Trib at 341810/1110414	15060105-13A	8.1	4A/5	None	Low dissolved oxygen (5), Nitrogen(4A), *E coli*(4A)	A&Wc
Tonto Creek (TON)	Trib at 341810/1110414 - Haigler Creek	15060105-013B	8.5	4A/5	None	Nitrogen(4A), *E.coli*(4A), Mercury in fish(5)	EPA FC[3]
Trib (UT2) to Tonto Creek	Headwaters - Tonto Creek	15060105-365	1.8	3	None	None	None
Trib (UT0) to Tonto Creek	Headwaters - Tonto Creek	15060105-372	2.9	3	None	None	None
Gordon Canyon Creek	Headwaters - Hog Canyon	15060105-336A	12.7	3	None	None	None
Haigler Creek	Headwaters - Trib at 341223/1110011	15060105-012A	15.4	2	Copper	None	None
Tonto Creek (TON)	Haigler Creek - Spring Creek	15060105-011	7.8	5	None	Mercury in fish	EPA FC

Waterbody	Reach Name	Reach Number	Miles Assessed	Assessed Category	Parameters with Exceedances*	Cause of Impairment	Impaired Uses
Thompson Draw	Headwaters - Tonto Creek	15060105-378	7.1	3	*E. coli*	None	None
Trib to Thompson Draw	Headwaters - Thompson Draw	15060105-379	0.8	3	None	None	None
Trib (UT1) to Tonto Creek	Headwaters - Tonto Creek	15060105-647	1.2	3	None	None	None
Deer Creek (D4E)	Headwaters - Rye Creek	15060105-018	11.9	3	None	None	None
Rye Creek	Headwaters - Tonto Creek	15060105-014	17.8	3	None	None	None
Spring Creek (SPi)	Headwaters - Tonto Creek	15060105-010	20.5	2	Dissolved oxygen, pH, thallium, nitrogen, phosphorous	None	None
Tonto Creek (TON)	Spring Creek - Rye Creek	15060105-009	19.5	5	None	Mercury in fish	EPA FC
Tonto Creek	Rye Creek - Gun Creek	15060105-008	18.6	5	None	Mercury in fish	EPA FC
Tonto Creek	Gun Creek - Greenback Creek	15060105-006	18.6	5	None	Mercury in fish	EPA FC
Tonto Creek	Greenback Creek - Roosevelt Lake	15060105-004	2.6	5	None	Mercury in fish	EPA FC
Lower Salt Subbasin							
Salt River	Stewart Mountain Dam - Verde River	15060106A-003	10.1	5	None	Dissolved oxygen	A&Ww
Fish Creek - Lower Salt River	Headwaters - Salt River	15060106A-583	16.3	3	None	None	None
Verde River Subbasin							
East Verde River	American Gulch - Verde River	15060203-022C	25.8	5	None	Arsenic	DWS, FBC
East Verde River	Ellison Creek - American Gulch	15060203-022B	20.3	5	None	Selenium	A&Ww
Verde River	Bartlett Dam - Camp Creek	15060203-004	6.6	5	None	Arsenic	DWS
American Gulch	Headwaters - No. Gila Co WWTP	15060203-448A	2.6	3	*E. coli*	None	None
American Gulch	No. Gila County WWTP - East Verde River	15060203-448B	3.6	3	*E. coli*	None	None
Bonita Creek	Headwaters - Ellison Creek	15060203-478	5.1	3	Dissolved oxygen, *E. coli,* SSC	None	None
City Creek	Headwaters - East Verde River	15060203-036	6.7	3	None	None	None
Dripping Springs	Springs Headwater - East Verde River	15060203-524	0.03	3	None	None	None
Patton Spring Draw	Headwaters - Webber Creek	15060203-506	2.2	3	None	None	None
Pine Creek (PIN)	Headwaters - Sycamore Creek	15060203-048	10	3	None	None	None
Sycamore Creek (SYM)	Headwaters - Verde River	15060203-002	34.6	3	Dissolved oxygen	None	None

Waterbody	Reach Name	Reach Number	Miles Assessed	Assessed Category	Parameters with Exceedances*	Cause of Impairment	Impaired Uses
Unnamed Trib to E. Fork Sycamore Creek	Headwaters - East Fork Sycamore Creek	15060203-262	1.3	3	None	None	None
Webber Spring	Spring Headwater - Webber Creek	15060203-516	0.04	3	None	None	None
East Verde River	Headwaters - Ellison Creek	15060203-22A	8.1	2	*E. coli*, biocriteria	None	None
Ellison Creek	Headwaters - East Verde River	15060203-459	10.8	2	*E. coli*	None	None
Pine Creek	Headwaters to Unnamed Trib at 342151/1112646	15060203-049A	8.4	1	None	None	None
Pine Creek (PIE)	Unnamed Trib at 342151/1112646 - East Verde R	15060203-049B	11.9	2	Arsenic, dissolved oxygen, *E. coli*	None	None
Roundtree Canyon	Headwaters - Tangle Creek	15060203-853	10.7	2	None	None	None
Sycamore Creek (SYH)	Headwaters - Verde River	15060203-055	13.1	2	Arsenic, dissolved oxygen	None	None
Verde River	West Clear Creek - Fossil Creek	15060203-025	23.6	2	pH	None	None
Verde River	Wet Bottom Mesa - Tangle Creek	15060203-019	8.2	2	None	None	None
Webber Creek	Headwaters - East Verde River	15060203-058	14.3	2	*E. coli*	None	None
Fossil Creek	Headwaters - Verde River	15060203-024	19.9	1	None	None	None
Agua Fria Subbasin							
Cave Creek	Headwaters - Cave Creek Dam	15060106B-026A	32.9	3	None	None	None

* These are water quality constituents that violate Arizona water quality standards

A&Wedw – Aquatic and Wildlife (effluent-dependent water) means use of an effluent dependent water by plants, wildlife, or other organisms

A&We – Aquatic and Wildlife (ephemeral) means use of an ephemeral water by plants, animals, and other organisms excluding fish

EPA FC – EPA designated impaired waters for fish consumption due to mercury in fish tissues

SSC – suspended sediment concentration; DWS - domestic water source; FBC - full body contact

Table 90. Water quality status of lakes on the Tonto National Forest

Water Body	Reach No.	Acres	Assessed Category	Parameters with Exceedances*	Cause of Impairment	Impaired Uses
Roosevelt Lake	15060103-1240	18,345	5	None	Mercury in fish	FC
Apache Lake	15060106A-0070	2,192	5	None	Low dissolved oxygen	A&Ww
Canyon Lake	15060106A-0250	447.8	5	None	Low dissolved oxygen	A&Ww
Saguaro Lake	15060106A	1,022	2	Dissolved oxygen, E. coli, nitrogen	None	None
Bartlett Lake	15060203-0110	2,375.5	3	Arsenic, dissolved oxygen	None	None
Horseshoe Lake	15060203-0620	1,982	3	Dissolved oxygen	None	None

* These are water quality constituents that violate Arizona water quality standards

FC = fish consumption; A&Ww = aquatic and wildlife (warmwater)

Key Findings

The Draft 2012/2014 305(b) Assessment Report (ADEQ 2014) assessed 663 miles of streams and almost 25,000 acres of lakes. Water quality in 66 miles of streams was found to be attaining all standards (category 1). These stream miles represent 85 percent of the category 1 streams within the context area and 10 percent of the assessed streams on the Tonto National Forest. Two of these streams, Fossil Creek and Canyon Creek, originate on the Mogollon Rim. The third stream, Cherry Creek, also originates in the high country north of Young and flows south to its confluence with the Salt River above Roosevelt Lake.

Water quality in 172 miles of streams and 1,022 acres of lakes (Saguaro Lake) was found to be attaining water quality standards for some uses (category 2). These stream miles represent 67percent of the category 2 streams within the context area and 26 percent of the assessed streams on the Tonto National Forest. These streams are scattered throughout the Upper Salt, Tonto, and Verde subbasins.

Water quality in 199 miles of streams and 4,357 acres of lakes (Bartlett and Horseshoe Lakes) are identified as category 3 (insufficient data to assess) waterbodies. These streams represent 52 percent of the category 3 stream miles in the context area and 30 percent of the assessed streams on the Tonto National Forest. Additional monitoring is necessary to complete the assessments on these waterbodies.

Twenty-nine surface waters (34 percent of the assessed stream miles) within the Tonto National Forest boundary are identified as either not attaining (category 4) or impaired (category 5). These include 225 miles of streams and 20,985 acres of lakes (Roosevelt, Apache, and Canyon Lakes). The majority of stream miles can be attributed to just three watersheds: Pinto Creek (39 miles), Queen Creek (35 miles), and Tonto Creek (72 miles).

The Pinto Creek watershed contains sources of natural copper mineralization as well as current and historical mining operations that potentially contribute copper loadings to the basin. Five stream reaches (39 miles) are identified as impaired or not attaining for copper and one of the five is also identified as impaired for selenium. A total maximum daily load for copper was completed in 2001. Arizona Department of Environmental Quality is attempting to set a site-specific copper standard for part of the basin due to natural copper mineralization. Cleanup actions have occurred at the Gibson Mine in the headwaters of Pinto Creek through a water quality improvement grant, and a CERCLA action has been initiated by the Forest Service for other abandoned copper mines on National Forest System lands in the headwaters. The Five Point tributary to Pinto Creek that is identified as impaired for copper is a high priority for preparation of a total maximum daily load. The reach of Pinto Creek from the confluence with West Fork Pinto Creek to Roosevelt Lake that is impaired for selenium is identified as a low priority for preparation of a total maximum daily load. Reducing nonpoint sources of pollution are a focus area for attaining water quality standards in the Pinto Creek watershed (ADEQ 2013).

Queen Creek watershed contains seven stream reaches totaling 35 miles that are impaired for copper. One of the reaches is also impaired for lead and selenium. The Queen Creek watershed is affected by historic mining activity. A new mine, the Resolution Copper Mine, is also proposed in this watershed. A copper total maximum daily load was initiated in 2004. At completion, this total maximum daily load should identify alternatives for bringing the impaired reaches into compliance with water quality standards. All seven watersheds are identified as a high priority for completing total maximum daily loads by Arizona Department of Environmental Quality.

Tonto Creek watershed contains six waterbodies (55.6 miles) that are designated as impaired due to mercury in fish tissue that exceeds the fish consumption standard. Roosevelt Lake at the mouth of Tonto Creek is also designated as impaired for mercury in fish tissue. A fish consumption advisory has been issued by Arizona Department of Environmental Quality for the affected reaches of Tonto Creek and Roosevelt Lake. The Department is conducting additional sampling to identify the source of mercury contamination and to support total maximum daily load development. Preparation of a total maximum daily load for the reaches of Tonto Creek affected by the fish consumption advisory is identified as a low priority in the 2012/14 305(b) report. Total maximum daily load development for Roosevelt Lake is identified as a medium priority.

Upper Tonto Creek watershed includes stream reaches that are impaired for nitrogen, phosphorous, low dissolved oxygen, and *E. coli.* Total maximum daily load assessments were completed for nitrogen and *E.coli* bacteria in 2006. Sources of contamination were identified as inadequate septic systems and recreational sources. Arizona Department of Environmental Quality has approved water quality improvement grants (grants that allocate funds from the Environmental Protection Agency for implementing nonpoint source pollution control projects) for improving septic systems at R-Bar-C Boy Scout Camp (2007), Tonto Baptist Camp (2008), and to Gila County (2006). The Forest Service has constructed new bathrooms, restricted vehicle access to maintain a buffer for the creek, and converted portions of the area from overnight camping to day-use only. A total maximum daily load for phosphorous has not yet been scheduled and is identified as a low priority for development by Arizona Department of Environmental Quality.

The Upper Tonto Creek watershed is identified as one of Arizona’s targeted watersheds. These watersheds are a priority in the state for Clean Water Act section 319 water quality improvement grants and other strategies to restore and protect water quality conditions.

Priority for development of total maximum daily loads for other impaired stream reaches on the Tonto National Forest are identified in table 91.

Table 91. Arizona Department of Environmental Quality priority ranking for the Tonto National Forest

Stream Reach/Lake	Cause of Impairment	Priority
Apache Lake	Low dissolved oxygen	Low
Canyon Lake	Low dissolved oxygen	Low
Salt River Canyon Creek to Cherry Creek	Selenium (total)	Low
Salt River Pinal Creek to Roosevelt Lake	Suspended sediment, nitrogen, phosphorous and *E. coli*	Medium
Salt River Stewart Mountain Dam to Verde River	Low dissolved oxygen	Low
Tonto Creek Headwaters to Trib at 341810/1110414	Low dissolved oxygen	Low
East Verde River Ellison Creek to American Gulch	Selenium (total)	Low
Verde River Bartlett Dam to Camp Creek	Arsenic (total)	Low

Source: ADEQ 2014

Current and Historical Disturbances

Current and historic disturbances are described in the “Watershed Extent and Perennial Streams” section. These disturbances are relevant to the water quality section as well. Current and historic mining impacts on water quality are particularly evident in the Pinal Creek, Pinto Creek, Mineral Creek, and Queen Creek watersheds in the Globe Ranger District. Roads and herbivory are widespread throughout the Tonto National Forest (except for wilderness and roadless areas for roads, and closed allotments for grazing). Dams and impoundments are found on the main stems of the Salt and Verde Rivers. Water withdrawals (both surface and groundwater) occur at various locations around the Tonto National Forest. Groundwater withdrawals occur primarily near mines and near towns and other developed areas. Drought and flooding occur throughout the national forest. Prescribed burns are planned primarily near the wildland urban interface, and wildfires can occur anywhere on the Tonto National Forest.

Reference Conditions

Insufficient information exists to characterize the historic range in variability of water quality. It is likely that prior to arrival of non-indigenous peoples, water quality was better than today. Native American settlements within what is today’s Tonto National Forest boundary were likely not of sufficient density to impact water quality (except possibly by firewood cutting that would reduce ground cover in close proximity to settlements and increase erosion and turbidity in nearby streams during storm events). In areas of high mineralization, naturally occurring sources of pollutants may have exceeded today’s water quality standards (for example, areas of copper mineralization).

In the absence of knowledge about the natural range of variation of water quality and departure from the natural range of variation, an alternative method to assess natural range of variation is used. The Arizona surface water quality standards provide an understanding of water quality conditions necessary for sustaining aquatic ecosystems and other beneficial uses. These standards will be used as the basis for determining the plan need for change.

Trends and Projections

Although there have been several Arizona Department of Environmental Quality water quality assessments in the last two decades, it is difficult to quantitatively identify trends. This is due to evolving and changing sampling and testing protocols, standards, and documentation. In addition, some standards have changed and the legislated requirement for “credible data” places a more stringent requirement on rigorous scientific data collection and analysis. An example of a change in standard is turbidity. This standard has been replaced with a suspended sediment concentration standard. Table 92 identifies the status of waterbodies assessed in the 2012/2014 305(b) assessment and 303(d) listing report.

A greater number of miles of streams were identified as impaired in the 2012/2014 303(d) list (list of impaired waterbodies) than in the 2010 303(d) list. Much of the increase is attributed to addition of 62 miles of Tonto Creek due to discovery of high levels of mercury in fish tissue. Part of the increase may also be due to a greater number of stream miles assessed on the Tonto National Forest in the 2012/2014 assessment (663 miles) than in the 2010 assessment (513 miles). However the percent of stream miles assessed as impaired increased from 21 percent in 2010 to 25 percent in 2012/2014.

Streams and waterbodies identified as impaired in Arizona Department of Environmental Quality's biannual 305(b)assessment and 303(d) listing reports have had or will have total maximum daily loads (TMDLs) prepared that recommend actions to bring water quality into compliance with surface water standards. Table 91 identifies the priority for developing total maximum daily loads for impaired waterbodies within the Tonto National Forest that do not yet have total maximum daily loads prepared and table 92 identifies the status of waterbodies with total maximum daily loads completed or in preparation.

Table 92. Status of waterbodies on the Tonto National Forest

Impaired Water	Pollutant Covered	Status	Types of Point or Nonpoint Sources	Approved by EPA	Implementation Plans/Activities
Queen Creek - Headwaters to Superior WWTP	Copper	Developing model.	mining	No	No
Queen Creek - Superior WWTP to Potts Canyon	Copper	Developing model.	mining	No	No
Christopher Creek - headwaters to Tonto Creek	*E. Coli*	The final *E. Coli* TMDL report has been completed.	wildlife, recreation, septic systems	7/26/2004	Various ongoing water quality improvement grant projects
Pinto Creek - headwaters to tributary at 33°19'27"/ 110°54'56"	Copper	EPA approved the Phase I TMDL in April 2001. ADEQ developing site-specific standard.	mining	04/01	CWA 319 project at Gibson Mine.
Pinto Creek - tributary at 33°19'27"/ 110°54'56" to Ripper Springs	Copper	EPA approved the Phase I TMDL in April 2001. ADEQ developing site-specific standard.	mining	04/01	CWA 319 project at Gibson Mine.
Pinto Creek - Ripper Spring to Roosevelt Lake	Copper Selenium	ADEQ developing site-specific standard for copper.	mining	No	No
Salt River - headwaters to Roosevelt Lake	Phosphorus	The final TMDL report has been completed.		1987	No
Tonto Creek - headwaters to tributary at 34°48'10"/111°04'14"	Nitrogen, *E Coli*	The final nitrogen and *E. coli* TMDL report has been completed	wildlife, recreation, septic systems, fish hatchery	6/05, 7/26/04	Various ongoing water quality improvement grant projects
Tonto Creek - tributary at 34°48'10"/111°04'14" to Haigler Creek	Nitrogen, *E Coli*	The final nitrogen and *E. coli* TMDL report has been completed.	wildlife, recreation, septic systems, fish hatchery	6/05, 7/26/05	Various ongoing water quality improvement grant projects
East Verde River - American Gulch to Verde River	Arsenic and boron	Initiating TMDL study	Under investigation	No	No

Source: http://www.azdeq.gov/environ/water/assessment/tmdl.html TMDL = total maximum daily load. CWA = Clean Water Act. EPA = Environmental Protection Agency. ADEQ = Arizona Department of Environmental Quality

Water quality in the streams identified in the tables above should improve as activities recommended in total maximum daily load analyses are implemented. Improved water quality has been documented in some waterbodies within the Tonto National Forest. Pinal Creek in the Globe-Miami area was listed as an impaired waterbody in 1988 due to contamination of ground and surface waters by acidity and heavy metals from mining operations that began in 1878. In 1989, the area was placed on the State's water quality assurance revolving fund priority list and in 1990, a consortium of mining companies formed the Pinal Creek Group to undertake remedial action in the area. A plume of polluted ground water migrating down gradient in the alluvium of Pinal Creek is captured by a well field, sent to a water treatment plant to remove contaminants, and then discharged to the perennial reach of Pinal Creek. In 2002, the perennial reach of Pinal Creek was delisted as an impaired waterbody. The 2012/2014 305(b) report lists Pinal Creek as category 2 (attaining some uses). The Verde River upstream of the confluence with Fossil Creek was listed as impaired for turbidity in 1990. Preparation of a total maximum daily load and implementation of best management practices to minimize the impacts of grazing resulted in delisting of this reach in 2010. Improvements in this reach should benefit downstream reaches of the Verde River as well. The Arizona Department of Environmental Quality has also reported improvements in impairments in Pinto Creek and anticipates reporting improvements in impairments to Tonto Creek (ADEQ 2014b).

Watershed Condition

Context Area

The context area is composed of watersheds that include at least 1 percent of the Tonto National Forest within the boundary of the watershed. Thirty-three watersheds are included within the context area.

Setting At and Below Planning Unit

Watershed condition is assessed at the subwatershed level within the boundaries of the Tonto National Forest. There are 197 subwatersheds that lie entirely or partly within the Tonto. Only subwatersheds with more than 5 percent of watershed area within the national forest are assessed. Where subwatersheds lie within the boundaries of more than one national forest, the national forest with the greatest percentage of subwatershed area completed the assessment for that subwatershed. After applying these screening criteria, 178 subwatersheds were assessed by the Tonto National Forest. Watershed conditions are not assessed at the watershed level; however, results of the subwatershed assessment have been aggregated upwards to display the number of subwatersheds and percent of watershed area in each condition class for each watershed.

Current Conditions and Disturbance Factors

In 2010, a study was completed to assess the risk of impaired conditions on the nearly 3,700 watersheds in the contiguous 48 states containing the national forests and grasslands that comprise the U.S. Forest Service's National Forest System (Brown and Froemke 2010). The study identified the risk of watershed impairment for each watershed based on a weighted set of indicators representing watershed stressors, at risk resources, and watershed condition variables. Stressors are identified as either human activities or influences, such as mining, that may place stress on the watershed and are amenable to change via human action; or natural events or conditions that may be affected by human activities, such as wildfire or soil erosion. At-risk resources are identified as human uses and concerns that are vulnerable to stressors. Examples include reservoirs susceptible to sedimentation, pristine streams, and endangered species habitat.

Watershed condition variables are instream or soil measures that indicate whether or not a problem exists, such as water quality (Brown and Froemke 2010). The assessment was limited to three types of watershed problems: sediments, nutrients, and toxics (dissolved metals and other toxic chemicals). These three problems capture four of the five most frequently cited causes of fresh water impairment (Brown and Froemke 2010). The three problems are evaluated independently and combined into an overall assessment.

Indicators representing watershed stressors were grouped into five categories: development group, roads group, farm and ranch group, mining group, and an “other” group that included stressors such as area of potentially damaging wildfire, atmospheric deposition-acid forming compounds, and dams. At-risk resources include waterbodies, water supply intakes, wild and scenic rivers, and threatened and endangered animal and plant species. Measures of watershed condition included water quality, water temperature, water quantity, fish populations, and soil quality. The assessment results in six intervals representing levels of risk of watershed impairment, with 1 being the lowest and 6 the highest risk of impairment.

Thirty-five watersheds intersect the Tonto National Forest; however, two of the watersheds were not assessed because the Tonto occupies less than 1 percent of each of these watersheds. The risk rating for the number of these watersheds in each risk rating category is displayed in table 93.

Table 93. Number of watersheds in rating categories

Risk of Impairment (rating)	Number of Watersheds in Rating Category
1-Lowest Risk	14
2	12
3	3
4	3
5-Highest Risk	1

The Tonto National Forest did not intersect any watersheds that received the highest risk rating (6). The majority of the watersheds received the two lowest risk ratings, which is also true of assessed watersheds on a national basis. The majority of the watersheds with risk ratings ranging from 3 to 5 border the west side of the Tonto National Forest and include substantial amounts of developed private lands within the Phoenix metropolitan area and other developed areas. Two watersheds with risk ratings of 3 within the Tonto National Forest are Upper Queen Creek and Pinal Creek. These watersheds include the communities of Superior and Globe-Miami and contain substantial amounts of both current and historic mining activities.

The relative effect of stressors used for assessing risk of watershed impairment on the risk ratings for the watersheds intersecting the Tonto National Forest are displayed in figure 50. These ratings represent the average values for the 33 watersheds assessed on the Tonto. Stressors with higher values (figure 51) have a greater effect on risk of watershed impairment. Stressors with the greatest effect include population growth, road stream crossings, and roads in riparian areas. Other stressors contributing to the rating include road density, grazing, area of potentially damaging wildfire, and atmospheric deposition. These ratings apply to the entire watershed not just the portion of the watershed within the national forest. The ratings displayed in figure 51 represent a risk of watershed impairment, not a measure of actual watershed impairment. An assessment of watershed condition on lands within the boundaries of the Tonto National Forest has also been conducted and is discussed in the section below.

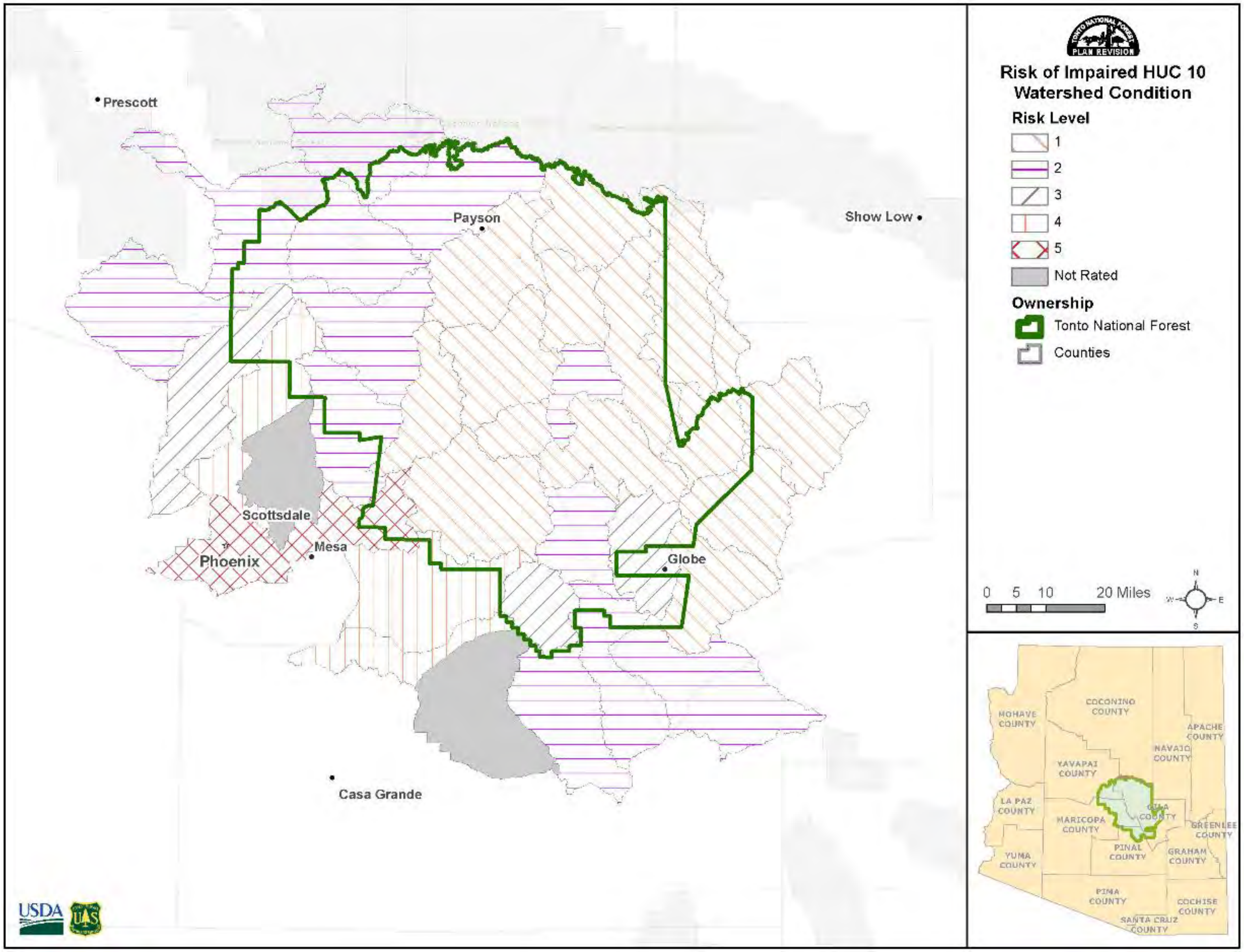


Figure 50. Risk of impaired 5th-level watersheds

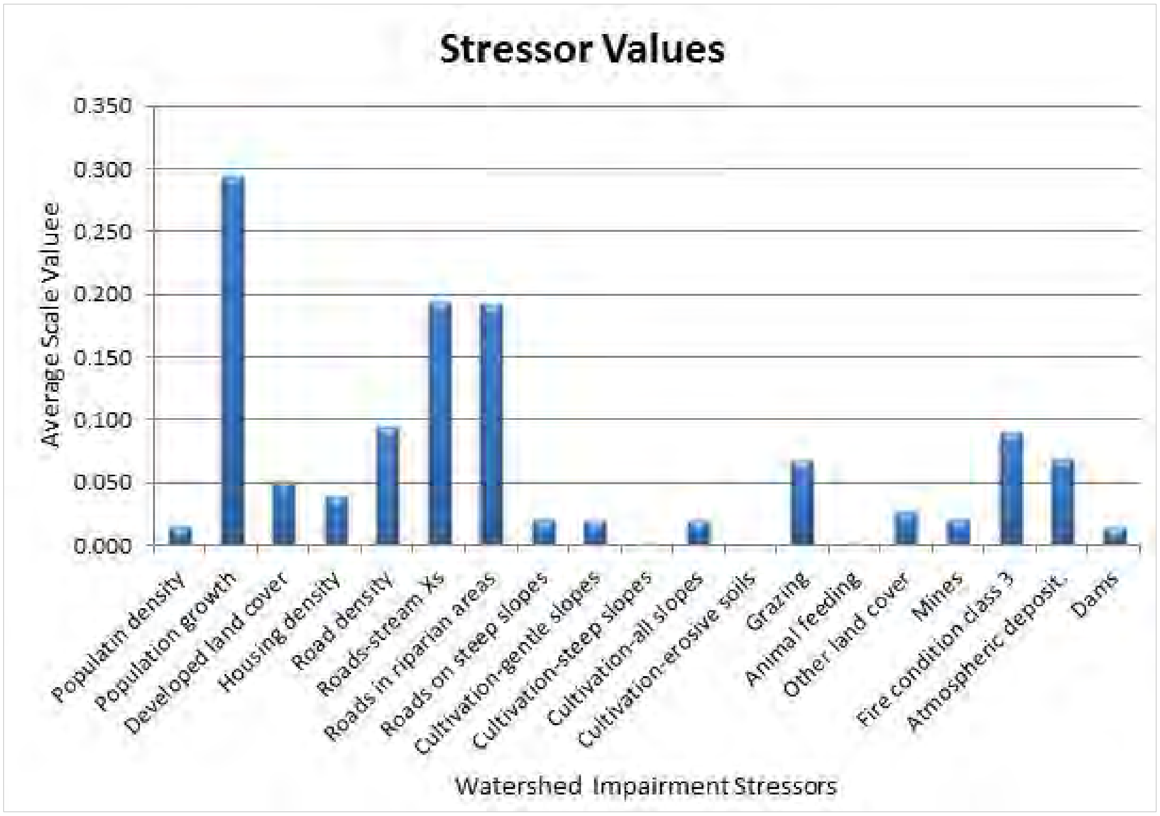


Figure 51. Watershed impairment stressor values

Note in figure 51 that scale values represent normalized values of the relative importance of various stressors that threaten watershed condition. Scale values range from 0.0 to 1.0 with lower values representing lower risk to watershed condition.

Planning Unit

Forest Service personnel conducted a national effort to assess the condition of all subwatersheds on National Forest System lands in 2010 and 2011. The Tonto National Forest evaluated 178 watersheds using the Watershed Condition Classification Technical Guide (Potyondy and Geier 2011) developed for this effort. The guide classifies watershed condition on the basis of a core set of 12 indicators, each containing 1 to 4 attributes that represent the underlying ecological functions and processes that affect soil and hydrologic function (Potyondy and Geier 2011). The attributes are scored, summed, and averaged to produce indicator scores, which are averaged within four process categories. The overall watershed condition score is then computed as a weighted average of the process category scores. The process categories, indicators, and attributes are displayed in figure 52. The final score for each subwatershed results in an overall rating of functioning properly, functioning at risk, or impaired function.

A properly functioning watershed is one that is functioning in a manner similar to natural wildland conditions (Karr and Chu 1998, Lackey 2001 in Potyondy and Geier 2011). A properly functioning watershed has minimal undesirable human impact on its natural, physical, or biological processes and is resilient and able to recover to the desired condition when disturbed by large natural disturbances or land management activities (Yount and Neimi 1990 in Potyondy and Geier 2011). A watershed has impaired function where some physical, hydrological, or biological threshold has been exceeded. Substantial changes to the factors that caused the degraded state are commonly needed to return the watershed to a properly functioning condition). A watershed that is functioning at risk lies somewhere in between; it is a watershed with moderate geomorphic, hydrologic, and biotic integrity relative to natural potential condition (Potyondy and Geier 2011).

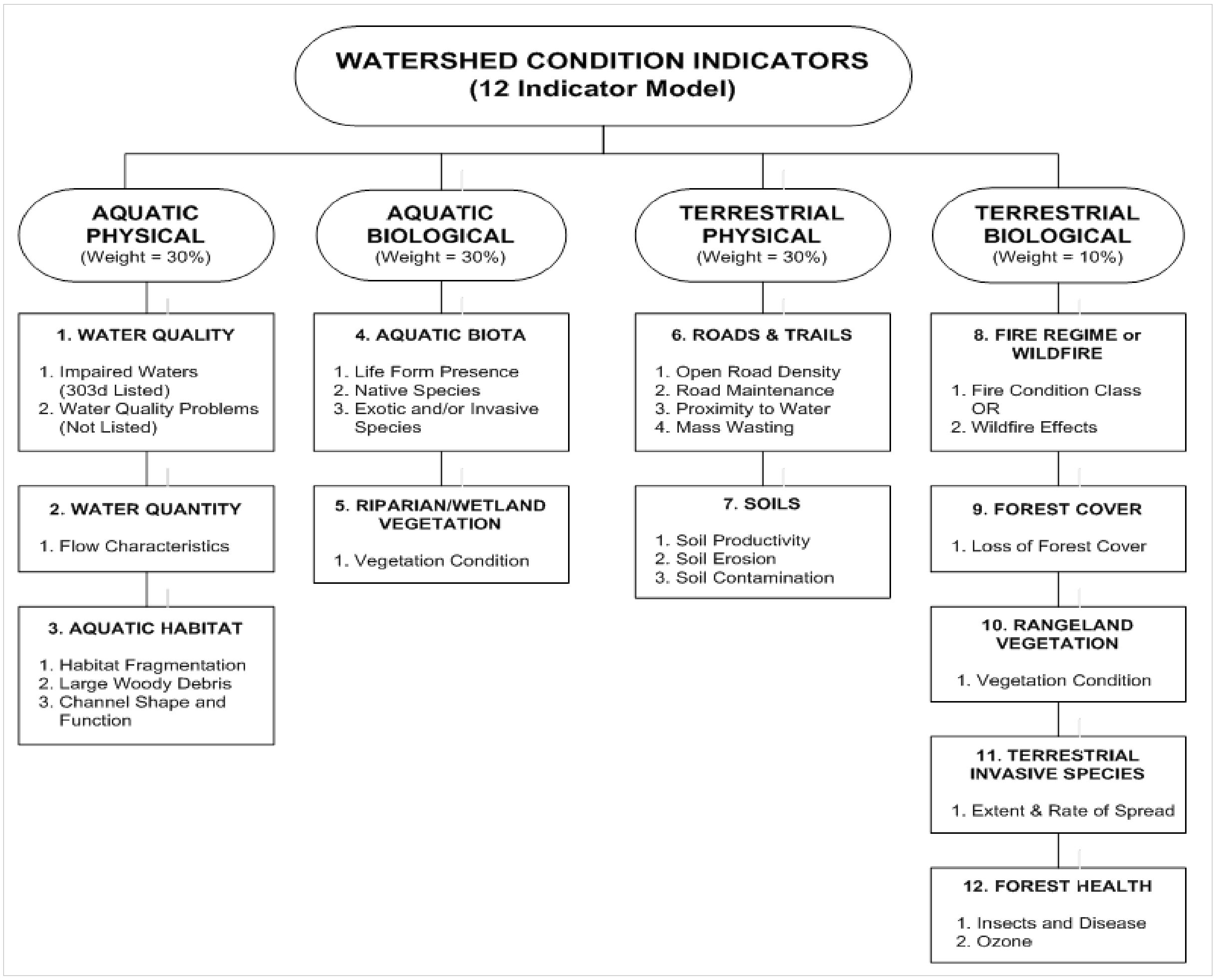


Figure 52. Watershed condition assessment attributes, indicators and process categories

The results of the Tonto National Forest assessment process are displayed by location and condition class in figure 53. Nineteen subwatersheds are rated as functioning properly, 122 as functioning at risk, and 37 as impaired function. Percent of watersheds in each condition class is displayed in figure 54.

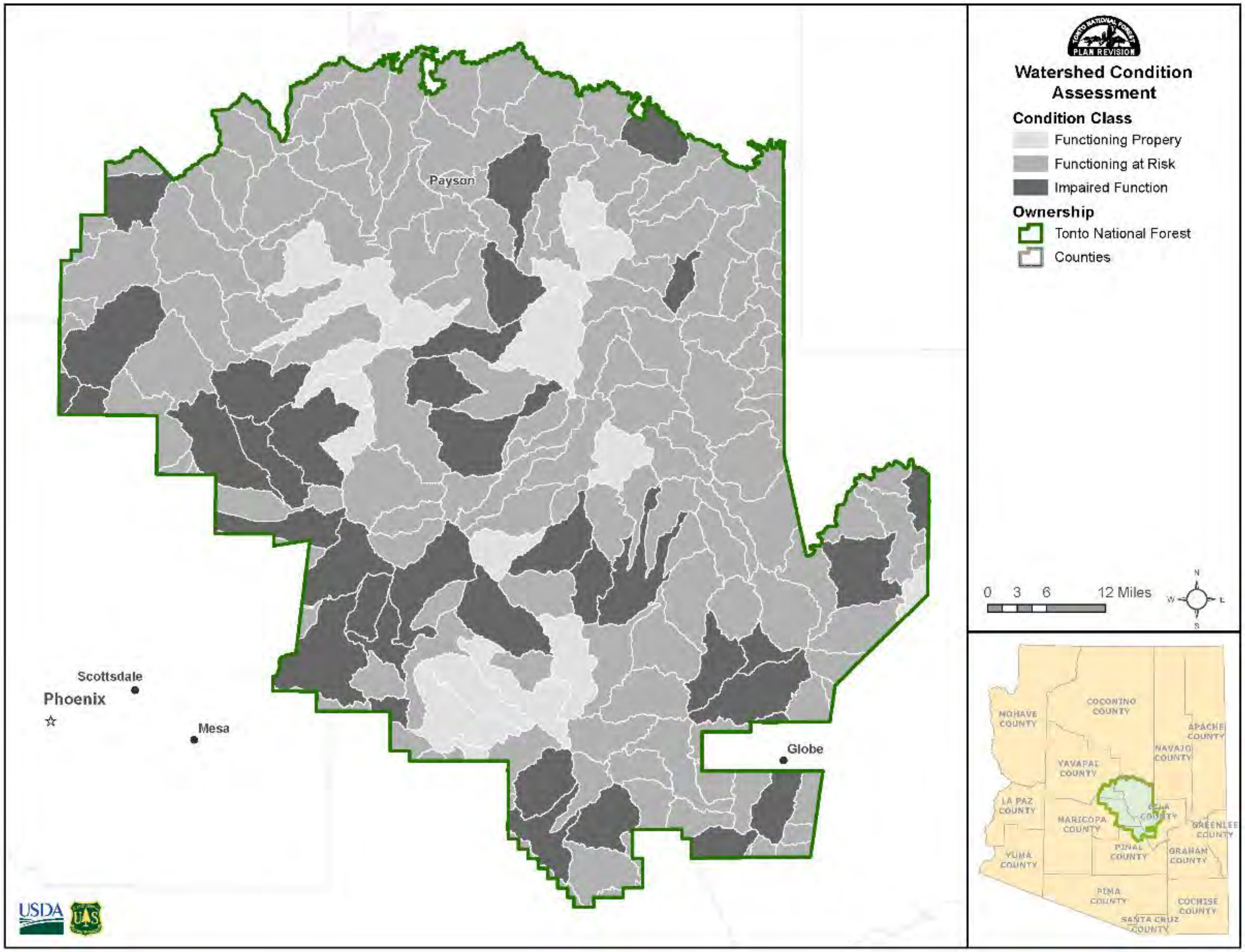


Figure 53. Condition of subwatersheds on the Tonto National Forest

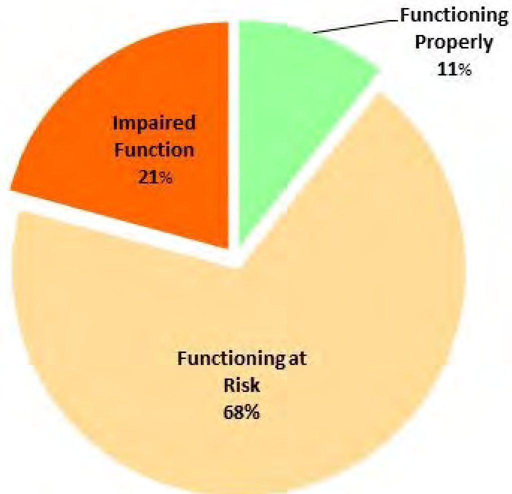
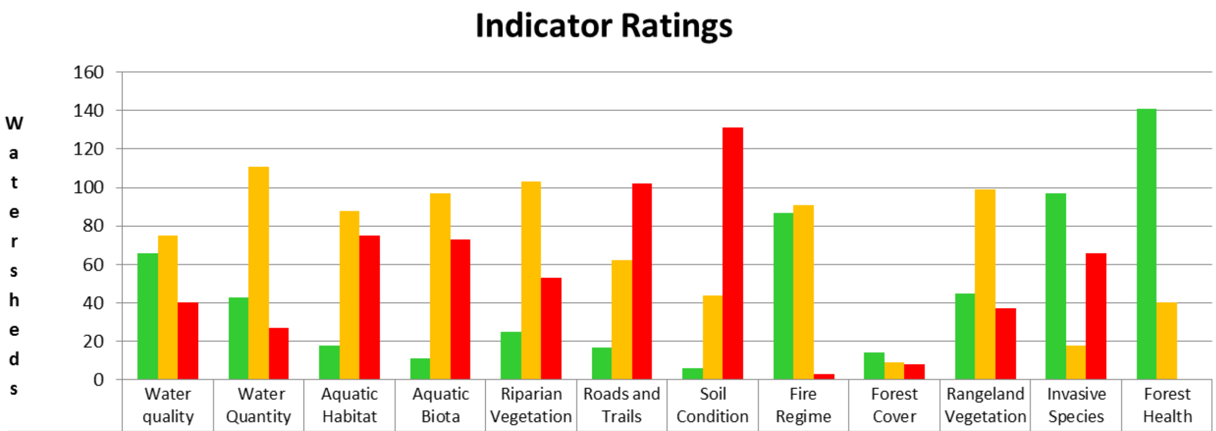


Figure 54. Percent of subwatersheds in each condition class

Figure 55 displays the number of subwatersheds in each assessment category for the 12 indicators used in the watershed condition assessment. Indicators that contributed substantially to functioning at risk and impaired function ratings for many watersheds and the attributes assessed for these indicators are:

- **Water Quantity** – accounts for changes to the magnitude, duration, or timing of the natural streamflow hydrograph. Watersheds with dams, diversions, major impoundments, or significant retention structures; groundwater pumping that affects stream base flows; effluent discharge; poor range conditions; recent fires; or urbanized areas affected this rating.
- **Aquatic Habitat** – accounts for habitat fragmentation, large woody debris, and channel shape and function. This rating was affected by road crossings that serve as fish barriers, the condition of riparian vegetation along stream channels that controls recruitment of large woody debris, and the condition of stream channels (Data for approximately 650 stream channel reaches on the Tonto exist to assess channel conditions).
- **Aquatic Biota** – accounts for distribution, structure, and density of native and introduced aquatic fauna. Most of the perennial streams on the Tonto support populations of nonnative fish and invertebrate species (including crayfish and bullfrogs)
- **Riparian and Wetland Vegetation** – accounts for function and condition of riparian vegetation along streams, waterbodies, and wetlands. Photo points, riparian surveys, and channel condition surveys were used to assess riparian conditions on the National Forest System lands.
- **Roads and Trails** – accounts for density, location, distribution and maintenance of the road and trail network. This indicator was influenced by low frequency of maintenance on level 2 roads (high-clearance, native-surface roads), location of roads close to stream channels, and to a lesser extent, by road density.
- **Soil Condition** – accounts for soil productivity, erosion, and chemical contamination. The Region 3 Soil Condition Class Rating Guide (USDA Forest Service 1999) that rates soils as satisfactory, impaired of unsatisfactory was used for this indicator



	Water quality	Water Quantity	Aquatic Habitat	Aquatic Biota	Riparian Vegetation	Roads and Trails	Soil Condition	Fire Regime	Forest Cover	Rangeland Vegetation	Invasive Species	Forest Health
Functioning	66	43	18	11	25	17	6	87	14	45	97	141
At Risk	75	111	88	97	103	62	44	91	9	99	18	40
Impaired	40	27	75	73	53	102	131	3	8	37	66	0

Figure 55. Subwatershed ratings for each watershed condition indicator

Other indicators, such as fire regime, rangeland vegetation, and invasive species also have a large number of watersheds rated as functioning at risk or impaired function but have only a small effect on the overall watershed condition rating due to the low weight assigned to these indicators in the assessment process. The large number of watersheds rated as impaired function for invasive species is due to the presence of red brome, an annual nonnative grass species, in the desert portions of the Tonto National Forest.

Individual scores for assessed attributes and summary ratings for each subwatershed are in the watershed condition assessment report. Watershed condition is rated good, fair, or poor, and these categories correspond to the functioning properly, functioning at risk, and impaired function categories described above.

Ratings for subwatersheds were aggregated upwards to the watershed level to display numbers of subwatersheds in each watershed by condition class and the percent of watershed area occupied by subwatersheds with the three condition class ratings. These results are displayed in table 94 below.

Table 94. Number and percent of subwatersheds in each watershed and their condition class ratings

Watershed Name	Number	Total	Good	Fair	Poor	% Good	% Fair	% Poor
Sevenmile Wash-Sycamore Creek	1504000702	4	1	3	0	17	83	0
Gilson Wash	1504000703	4	0	4	0	0	100	0
Dripping Springs Wash-Middle Gila River	1505010001	1	0	1	0	0	100	0
Mineral Creek - Middle Gila River	1505010002	3	0	2	1	0	68	32
Box O Wash-Middle Gila River	1505010003	2	0	2	0	0	100	0

Watershed Name	Number	Total	Good	Fair	Poor	% Good	% Fair	% Poor
Upper Queen Creek	1505010004	5	0	2	3	0	36	44
Paisano Wash - Middle Gila River	1505010007	1	0	1	0	0	100	0
Middle Queen Creek	1505010008	5	2	2	1	15	68	17
Sawmill Creek - Upper Salt River	1506010302	2	0	1	1	0	22	78
Canyon Creek	1506010303	6	0	6	0	0	100	0
Cherry Creek	1506010304	9	0	8	1	0	97	3
Salt River Draw - Upper Salt River	1506010305	5	0	4	1	0	67	33
Pinal Creek	1506010306	7	0	2	5	0	18	82
Pinto Creek	1506010307	6	0	6	0	0	100	0
Salome Creek	1506010308	5	1	4	0	23	77	0
Upper Salt River - Theodore Roosevelt Lake	1506010309	10	0	8	2	0	74	26
Spring Creek	1506010501	6	1	5	0	17	83	0
Haigler Creek - Tonto Creek	1506010502	7	1	5	1	9	78	13
Rye Creek - Tonto Creek	1506010503	11	2	6	3	14	65	21
Gun Creek - Tonto Creek	1506010504	9	1	6	2	21	51	28
Tonto Creek - Theodore Roosevelt Lake	1506010505	4	1	2	1	23	41	36
Lower Salt River - Apache, Canyon, and Saguaro Lakes	1506010601	13	4	5	4	39	26	35
Lower Salt River Below Saguaro Lake	1506010603	2	0	1	1	0	10	90
East Verde River	1506020302	10	0	10	0	0	100	0
Fossil Creek - Lower Verde River	1506020303	1	0	1	0	0	100	0
Tangle Creek - Lower Verde River	1506020304	9	1	8	0	11	89	0
Lower Verde River - Horseshoe and Bartlett Reservoirs	1506020305	9	4	3	2	31	36	33
Mesquite Wash - Sycamore Creek	1506020306	5	0	4	1	0	78	22

Watershed Name	Number	Total	Good	Fair	Poor	% Good	% Fair	% Poor
Camp Creek - Lower Verde River	1506020307	5	0	2	3	0	19	81
Bishop Creek	1507010204	5	0	4	1	0	68	32
Agua Fria River - Lake Pleasant	1507010205	2	0	2	0	0	100	0
Cave Creek - Arizona Canal Diversion Channel	1507010206	2	0	2	0	0	100	0
New River	1507010208	3	0	0	3	0	0	100

Key Findings

Although watershed stressors used to identify risk of watershed impairment for the context area watersheds are not directly related to the watershed impacts used to identify condition classes of subwatersheds in the Planning Area there is some connectivity between the two sets of variables. Table 95 relates the stressors by stressor group from the risk of impaired conditions of watersheds study (Brown and Froemke 2010) to the watershed conditions indicators in the Watershed Condition Classification Technical Guide (Potyondy and Geier 2011). The table identifies the watershed condition indicators that would be affected by the stressors from the Brown and Froemke study and the type of impact these stressors would have on the indicators.

Table 95. Watershed impairment stressors and watershed condition indicators

Watershed Stressor Group (Brown and Froemke 2010)	Watershed Indicator Impacts (Potyondy and Geier 2011)
Development Group Population density Population growth Developed land cover Housing density	Water Quality – sediment, nutrients, toxics Water Quantity – increased runoff/peak flows, increased use, decreased base flows Aquatic Habitat – loss and degradation Riparian/wetland Vegetation – decline in extent and condition Soil Condition – erosion, compaction, degraded condition Invasive Species - increase
Roads Group Road density Road-stream crossings Roads in riparian areas Roads on steep slopes	Water Quality – sediment Water Quantity – increased runoff Aquatic Habitat – loss and degradation Riparian/wetland Vegetation – decline in extent and condition Soil Condition – erosion, decline in condition Invasive Species - increase
Farm and Ranch Group Cultivation Livestock grazing Confined animal feeding	Water Quality – sediment, nutrients, toxics Water Quantity – increased runoff and use Aquatic Habitat – loss and degradation Riparian/wetland Vegetation – decline in extent and condition Soil Condition – erosion, compaction, decline in condition Invasive Species - increase

Watershed Stressor Group (Brown and Froemke 2010)	Watershed Indicator Impacts (Potyondy and Geier 2011)
Mining Group Mining land cover Mines	Water Quality – sediment, toxics Water Quantity – increased runoff and use Aquatic Habitat – loss and degradation Riparian/wetland Vegetation – decline in extent and condition Soil Condition – erosion, Invasive Species - increase
Other Group Area of potentially damaging wildfire Atmospheric deposition-acid forming compounds Dams	Water Quality – sediment, nutrients, toxics Water Quantity – increased runoff/peak flows Aquatic Habitat – loss and degradation Riparian/wetland Vegetation – decline in extent and condition Soil Condition – erosion Invasive Species – increase Forest Cover – loss and change of composition

Almost 80 percent of the watersheds in the context area are in the two lowest risk categories for watershed impairment, this compares with only 65 percent of watersheds nationwide but is similar to the 80 percent of watersheds in the six western regions of the Forest Service. Stressors creating the greatest risk of impairment in the context area include population growth, road related stressors (road density, road stream crossings, and roads in riparian areas), grazing, areas of potentially damaging wildfire, and atmospheric deposition.

In terms of the subwatersheds within the planning unit, figure 54 identifies that 11 percent of the subwatersheds within the Tonto National Forest are categorized as functioning properly while on a national basis a little more than 50 percent of National Forest System subwatersheds are rated as functioning properly. Figure 54 also identifies that 21 percent of the subwatersheds within the planning area have impaired function. This compares with only 3 percent of National Forest System subwatersheds nationally with impaired function. Factors influencing the condition of many of the subwatersheds on the Tonto National Forest are displayed in figure 55. Factors having the greatest impact on subwatershed condition include: water quantity, aquatic habitat, aquatic biota, riparian and wetland vegetation, roads and trails, and soil condition.

Reference Conditions

The reference condition for watersheds is functioning properly. Watersheds that are functioning properly have terrestrial, riparian, and aquatic ecosystems that capture, store, and release water, sediment, wood, and nutrients within their range of natural variability. Properly functioning watersheds create and sustain functional terrestrial, riparian, aquatic, and wetland habitats that are capable of supporting diverse populations of native aquatic and riparian dependent species (Potyondy and Geier 2011). The Watershed Condition Framework Report (Williams et al. 1997 in USDA Forest Service 2011) identifies five important characteristics of properly functioning watersheds:

1. They provide for high biotic integrity, which includes habitats that support adaptive animal and plant communities that reflect natural processes.
2. They are resilient and recover rapidly from natural and human disturbances.
3. They exhibit a high degree of connectivity longitudinally along the stream, laterally across the floodplain and valley bottom, and vertically between surface and subsurface flows.

4. They provide important ecosystem services, such as high-quality water, the recharge of streams and aquifers, the maintenance of riparian communities, and the moderation of climate variability and change.
5. They maintain long-term soil productivity.

These characteristics identify reference conditions for watersheds. In general the greater the departure from these conditions the more impaired watershed condition is likely to be.

Trends and Projections

Context Area

Much of the Phoenix metropolitan area lies within the 5th-level watershed context area. Population growth in the Phoenix metropolitan area has slowed since the 2008 recession. Figure 51 identifies population growth as the stressor with the greatest impact on risk of watershed impairment. With population growth slowing, the threat from this stressor should decline. Although population density is not a major stressor on watershed condition, it is highly correlated with the developed land cover, housing density, and road density stressors and less highly correlated with the road-stream crossings stressor (Brown and Froemke 2010). These stressors do have a substantial effect on risk of watershed impairment. Despite the decline in population growth rate, population continues to grow. As growth continues, more land is converted to housing and associated infrastructure (like roads and utilities) to support the growth. These factors should continue to pose a risk to impaired watershed conditions within the context area.

Livestock grazing is highly correlated with measures of agricultural activity. Conversion of agricultural land to residential subdivisions may reduce livestock grazing to a small degree in the context area. Efforts are being made both within and beyond the national forest boundary to reduce fuel buildups, particularly around housing developments to reduce the risk of damaging wildfire. In terms of the atmospheric deposition stressor there have been three areas within the Tonto National Forest identified as nonattainment areas for particulates: Payson, Globe-Miami area, and Maricopa County. The Payson and Globe-Miami areas are no longer in violation of the PM 10 (particulate matter smaller than 10 microns in diameter) standards and violation of the PM 2.5 (particulate matter smaller than 2.5 microns in diameter) standard in Maricopa County is attributed to the urban area rather than to conditions or activities occurring on the Tonto National Forest. On an overall basis, air quality within the Tonto National Forest seems to be improving, although the air quality impacts of continued growth in Maricopa County are uncertain.

Planning Unit

Watershed conditions for subwatersheds are scheduled to be reassessed in 2016 to assess changes in watershed condition class. The Watershed Condition Classification Technical Guide implements the watershed condition assessment requirements of the watershed condition framework (USDA Forest Service 2011), which “is a comprehensive approach for proactively implementing integrated restoration on priority watersheds on national forests and grasslands”. The watershed condition framework consists of a six-step process to restore the condition of watersheds on National Forest System lands. The first step was to classify the condition of National Forest System subwatersheds which has been described above. The second step is to identify a small set of priority watersheds to target for improvement.

The Tonto National Forest has identified the watersheds listed below and displayed in figure 56 as its priority watersheds:

- Lower Fossil Creek – based on water quality impacts from recreational use
- Horton Creek-Tonto Creek – based on impaired waterbody status
- Parallel Canyon-Cherry Creek – based on fire regime condition class
- Middle Spring Creek – based on nonnative fish species
- Camp Creek – based on off-highway vehicle impacts

The list of priority watersheds are likely to be revised based on a quantitative assessment of activities that can be implemented on National Forest System lands that are likely to improve the condition of targeted watersheds.

The third step is to develop watershed restoration action plans that identify comprehensive project-level improvement activities. The Tonto National Forest has developed one watershed restoration action plan that targets the Camp Creek watershed on the Cave Creek Ranger District. The fourth step is to implement the plan. The Tonto is currently implementing the Camp Creek plan by obliterating unauthorized and uninventoried motorized vehicle routes in the watershed. The fifth and sixth steps are to track accomplishments and monitor improvements. Trends and indicators used to rate watershed condition are described below.

- **Water Quality** – Preparation of total maximum daily loads and implementation of total maximum daily load implementation plans by Arizona Department of Environmental Quality, watershed improvement plans by local watershed partnerships in conjunction with technical support from Arizona Department of Environmental Quality and the University of Arizona, Arizona NEMO[8] plans, and watershed restoration action plans by the Tonto National Forest should result in long-term improvements to water quality.
- **Water Quantity** – Little change to conditions affecting water quantity are expected in the short term. Major dams and diversions are expected to continue into the future. Growth in Tonto Basin, Pleasant Valley, Globe-Miami, Payson-Star Valley, and the Verde Valley areas could increase groundwater withdrawals and potentially reduce base flows in Tonto Creek, Cherry Creek, Pinal Creek, East Verde River, Houston Creek, and the Verde River. Groundwater pumping by the Carlota Copper mine that affects stream flow in Haunted Canyon and Pinto Creek should decline as Carlota begins closure activities. Increased groundwater pumping by the Pinto Valley Mine may offset reduced impacts to Pinto Creek from the Carlota Mine.
- **Aquatic Habitat** – Habitat fragmentation, large woody debris, and channel shape and function are likely to remain unchanged except in areas where riparian and wetland conditions are improving.
- **Aquatic Biota** – Presence of nonnative aquatic species and poor habitat conditions result in functioning at risk and impaired function ratings for many subwatersheds. Removal of nonnative species is difficult and expensive. Presence of these species is not expected to change substantially into the future. In a number of waterbodies, nonnative species are introduced to provide sport fishing opportunities. Removal of nonnative species has occurred in a few locations (Fossil Creek and Arnett Creek) and is proposed in Spring Creek. Except for a few locations, aquatic biota conditions are expected to remain similar to current conditions.

[8] Arizona Nonpoint Education for Municipal Officials

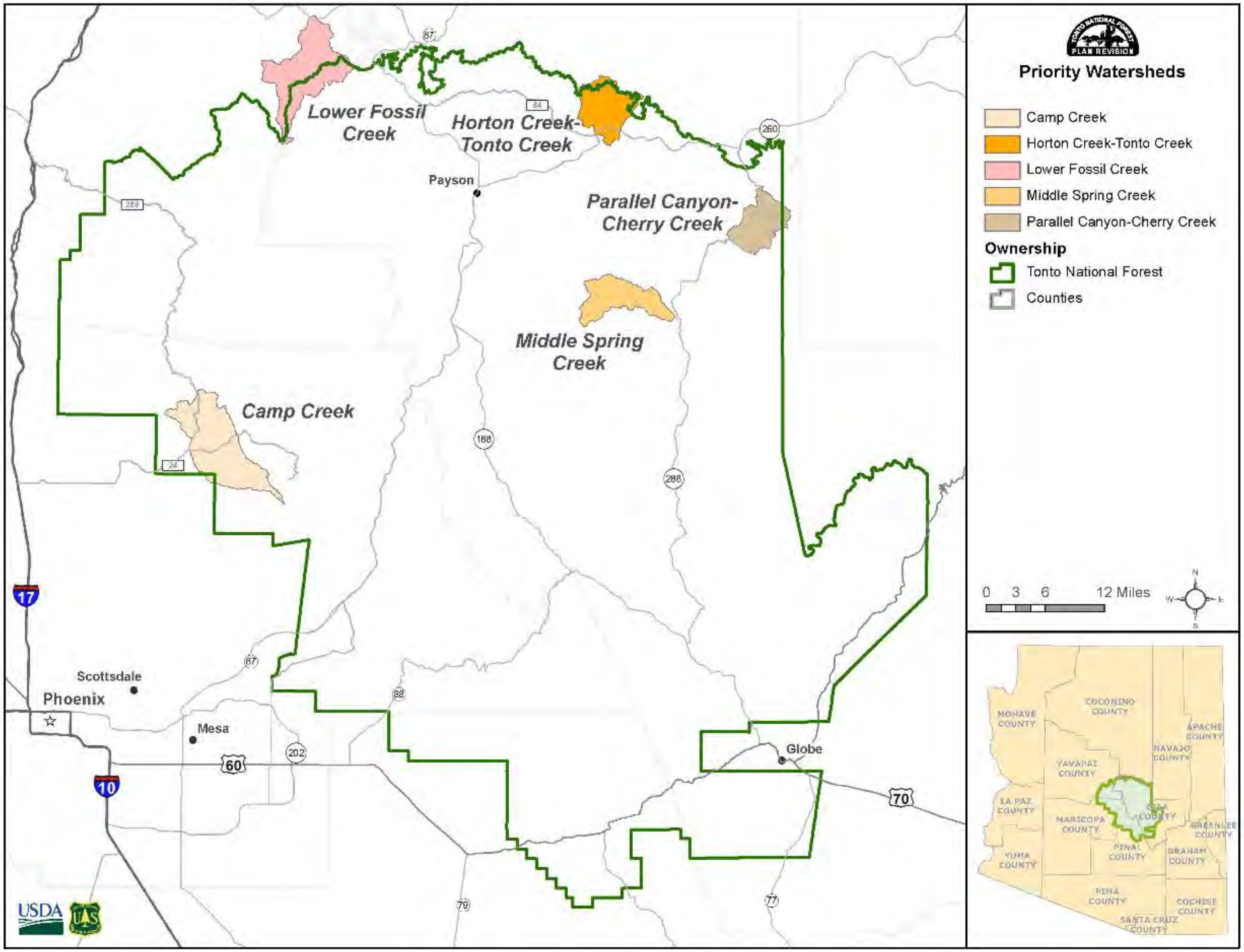


Figure 56. Priority watersheds on the Tonto National Forest

- **Riparian and Wetland Conditions** – Riparian and wetland areas are affected by grazing, roads and trails, groundwater pumping and surface water diversions, recreation, and uncharacteristic fire. Riparian conditions have improved in a few locations such as Lime Creek on the Cave Creek district since the watershed condition classification was completed. Many of the factors affecting riparian and wetland conditions are not expected to change substantially into the future, consequently riparian and wetland conditions are also expected to remain similar to current conditions except where localized changes in management and implementation of projects should result in improvements to condition class.
- **Roads and Trails** – The Tonto National Forest is currently developing a motorized travel management plan. The alternatives considered in the plan would not result in an increase in the miles of motorized routes on the Tonto and could result in a decrease. It is likely some improvement in road and trail conditions can be expected into the future.
- **Soil Condition** – Soil conditions are expected to remain similar to current conditions. Improvements to soil condition is a slow process occurring over a long time (many years or decades)
- **Fire Regime Condition Class** – Mechanical treatments and prescribed fire in wildland-urban interface areas and reintroduction of natural fire is expected to result in improvements to fire regime condition class
- **Rangeland Vegetation** – livestock grazing is an authorized use of National Forest System lands. Severe overgrazing by livestock occurred historically on the Tonto National Forest and resulted in degraded rangeland conditions. Livestock numbers have been reduced, and livestock on National Forest System lands are managed through development of allotment management plans. Continued livestock grazing is expected to maintain current rangeland vegetation conditions into the future. The ability to respond to drought conditions and the ability to monitor upland and riparian conditions and move livestock when prescribed vegetation utilization levels have been reached will be an important factor in preventing current conditions from declining.
- **Invasive Species** – Grass species, such as fountain grass and buffel grass, are expanding but are limited to the desert and semi-desert areas. Forb species, such as star thistle and resin bush, are present but do not appear to be expanding their range. Shrub and tree species, such as tree of heaven, are present but not spreading. Riparian species, such as salt cedar, are widely present in riparian areas but also don’t seem to be expanding or creating monoculture conditions in riparian areas. Areas of greatest risk for invasion by nonnative species are disturbed areas such as road ways, trailheads, and recently burned areas.

The trend for overall watershed condition depends on the trends of the individual indicators and the interactions between them. Under current conditions, 11 percent of subwatersheds are functioning properly, 68 percent are functioning at risk, and 21 percent have impaired function. Factors with the greatest impact on current conditions are water quality, aquatic habitat, aquatic biota, riparian vegetation, roads and trails, and soil condition. Some factors can respond quickly to management. Examples include riparian vegetation, and roads and trails. Some indicators respond more slowly and require improved management over a long time period (such as soil condition and fire regime condition class). Some factors, such as nonnative aquatic species and nonnative plant species in the desert portions of the Tonto, may be very difficult to improve. Focusing restoration resources on targeted watersheds through preparation and implementation of watershed restoration action plans and availability of other plans implemented by public and private partners (such as State-based total maximum daily load and watershed improvement plans) should enable improvements in watershed condition and result in a long-term trend of improvement in watershed conditions.

Aquatic Biota

The condition of watersheds and and aquatic resources within and outside the Tonto National Forest boundary influences the status and trend of aquatic species within the Tonto, particularly use and management of groundwater and constructed waterways and climate conditions. This section focuses on the status and trend of aquatic biota and their habitats within the Tonto National Forest boundary.

Analysis Methods

Prior to European settlement, only native aquatic species (such as fish and aquatic macroinvertebrates) were present in watersheds of the Gila River basin in Arizona. This pre-European status of aquatic biota is used as the reference condition. Perennial waters with no undesireable nonnative species or low abundance of these species strongly contribute to persistence of native fish species on the Tonot. Though, it is likely that aquatic habitat conditions have changed over time, it is assumed the total current perennial stream miles should only be inhabited by native aquatic species; therefore, the current quantity of perennial stream miles is used as reference. We used watershed condition information for each zone from the "Watersheds and Water Resources" section and distribution information on nonnative aquatic species to examine the risk of persistence for fish species that occupy those zones. We assumed conditions that represent normative hydrologic function and variability will support viability of native aquatic biota on the Tonto. The current watershed condition for aquatic biota habitat is assessed at the U.S. Geological Survey water classification catalog unit, 4th-level subbasin scale due to limited information about fish species at finer scales (that is, 5th-level watershed scale, figure 57).

Current Condition and Trend

Historically, 14 native fish species occurred within the context area (subbasin) scale (table 96). Of these 14 native fish species found on the Tonto National Forest, 10 are under Federal protection due to the alteration of habitats and introduction of nonnative species. All 14 species still occur, although five species (36 percent) that were once considered extirpated from the context area have been reintroduced. Colorado pikeminnow (*Ptychocheilus luscious*) and razorback sucker (*Xyrauchen texanus*) have been reintroduced to the Verde River upstream of Horseshoe Reservoir. These reintroductions are supplemented with annual (typically) stockings, but natural recruitment has yet to be documented for either species. Razorback sucker have also been reintroduced in Fossil Creek but there is no evidence that they have established in the creek (Love-Chezem et al. 2015).

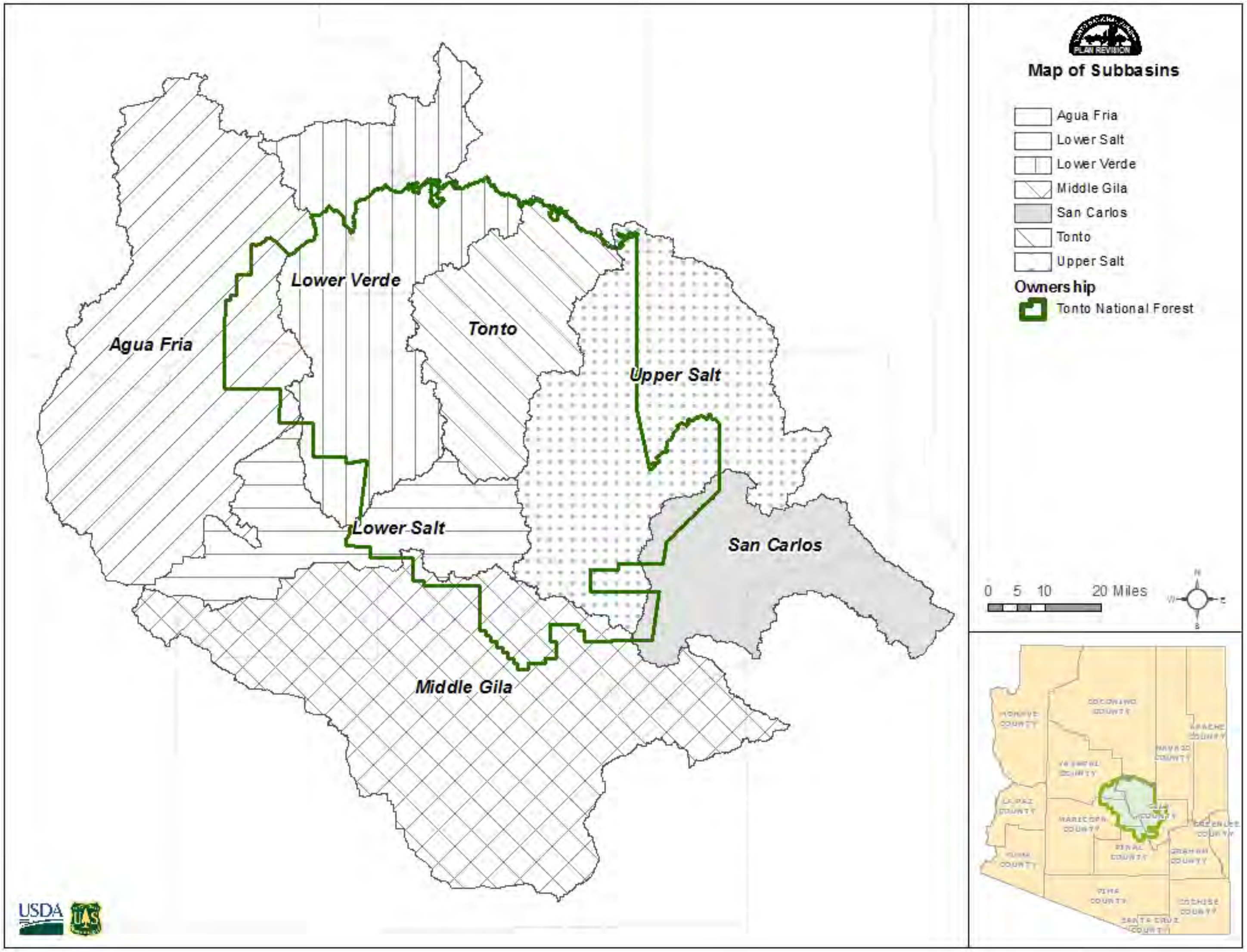


Figure 57. Map of subbasins (4th-level) used for aquatic biota assessment on the Tonto National Forest (TNF)

Table 96. Departure ranking of occurrences of native relative to nonnative fish species for current (C) and reference (R) conditions on the Tonto National Forest at the subbasin scale

Subbasin Name	Longfin Dace	Speckled Dace	Desert Sucker	Sonora Sucker	Desert Pupfish	Gila Topminnow	Gila Chub	Headwater Chub	Roundtail Chub	Colorado Pikeminnow	Razorback Sucker	Spikedace	Loach Minnow	Gila Trout	Current/Historical Number of Native Species	Number of Nonnative Fish Species	Percent Depature of Current From Historical*	Departure Ranking
San Carlos	N	N	N	N	N	C	N	N	N	N	N	N	N	N	1/1	0	0	L
Middle Gila	C	N	C	C	C	C	R	N	N	R	R	R	R	N	5/10	10	50	M
Upper Salt	C	C	C	C	N	C	N	N	C	R	R	R	R	N	6/10	11	40	M
Tonto	C	C	C	C	C	C	N	C	N	N	N	R	R	N	7/9	10	22	L
Lower Salt	C	N	C	C	C	C	N	N	C	R	R	R	R	N	6/10	16	40	M
Lower Verde	C	C	C	C	N	C	N	C	C	C	C	C	C	C	12/12	15	0	L
Agua Fria	C	C	C	N	C	C	C	N	N	R	R	R	R	R	6/11	15	45	M

* 0 to 33 percent departure = low (L) risk ranking; 34 to 66 percent = moderate (M) risk ranking; 67 to 100 percent = high (H) risk ranking

C = current; R = reference (pre-European); N = native fish species were not historically present within watershed and are still not present

Spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) have also been reintroduced in Fossil Creek. Natural reproduction has been documented in the spikedace population but not in the loach minnow population (Robinson 2015). Additionally, Gila trout (*Oncorhynchus gilae*) were once considered extirpated from within the context area scale but were reintroduced in Dude Creek on the Tonto in October 2015. Historically, the creek supported a viable population of nonnative rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*), but those populations were eliminated following the Dude Fire of 1990. Efforts in the late 1990s to restore Gila trout following the Dude Fire were unsuccessful, likely due to additional wildfire in the mid-2000s and subsequent post-fire ash flows. Aquatic habitat conditions in Dude Creek were considered sufficiently recovered by 2015 that the creek was deemed suitable for the reintroduction that occurred in 2015. This population of Gila trout was augmented in 2016 and will be again in 2017 with additional stockings, and will be monitored to document the success of the reintroduction. There are plans to reintroduce Gila trout to other streams (examples include Chase and Haigler Creeks) on the Tonto National Forest in the future.

We considered perennial stream habitats with low abundances or lacking nonnative species to be key factors associated with native aquatic biota viability on the Tonto. Stream miles with native fish only were considered to reflect reference conditions with risk assessed as low at 0 to 33 percent departure, moderate at 34 to 66 percent departure, and high when greater than 66 percent departed (table 97).

Most perennial stream miles are found in the Lower Verde and Tonto Basin zones, a factor likely reflected in the higher fish species diversity found in these zones (table 117 on page 367). In general, the Tonto Basin, Lower Verde, and Upper Salt subbasins were found to have proportional representation of perennial stream miles that reflected reference conditions, whereas the Agua Fria was under represented and the Lower Salt was over represented (misrepresented due to the influence of the constructed waterways that contain high numbers of nonnative, undesireable species).

Many of the perennial streams and rivers of the Lower Salt zone and the mainstem lower Verde River are altered due to water impoundments and presence of predatory and competitive nonnative species such as crayfish and introduced sportfish species (Rinne 1995). Nonnative sportfishes have been introduced broadly and are managed in constructed waters and high use streams by Arizona Game and Fish Department. While enhancing recreational users experiences in areas of the Tonto National Forest, nonnative fish species add risk to native fish species viability through competition, predation, and disease. Nonnative invertebrates, such as Quagga mussel, and plant species also inhabitat constructed waters of the lower Salt zone, often with unknown impacts to aquatic biota. Additionally, constructed waters with existing reservoir systems have altered normal hydrologic regimes and environmental conditions (such as water temperature and constituents) to which native species have adapted. Additional information about sport fishing can be found in Volume II of the assessment, Chapter 4 Multiple Uses, “Fish, Wildlife, and Plants” section.

Disturbances

Most, if not all, native fish species have shown declines in their distribution within the plan scale since European settlement. Numerous factors have led to the decline in distribution of native aquatic species in the watersheds of the Gila River basin on the Tonto National Forest. Introduction of nonnative fish species has led to competition, predation, introduction of disease and hybridization with native species. Green sunfish is the primary nonnative fish species responsible for the decline of native fish on the Tonto. Flathead and channel catfish have effects in larger systems but their distribution is not nearly as widespread as green sunfish. Other nonnative aquatic species that impact native aquatic species include crayfish which are distributed through most of the perennial streams on the Tonto National Forest. Bullfrogs, like catfish, are present in some of the larger stream systems and are likely having impacts on native fish, but they are not distributed as widely as crayfish.

Habitat modification and fragmentation has occurred from dam construction, conversion to agricultural uses, dewatering, road construction, cattle grazing, and timber harvest. Additionally, catastrophic wildfires have led to declines in the distribution and abundance of native aquatic biota. Wildfires typically occur just prior to the monsoon season in Arizona. Subsequent monsoon rains cause flooding that carries ash that kill fish and severely alter habitats, often taking years to recover. As a result of all disturbances, native fish populations have been reduced from a large interconnected population to isolated populations in remote headwater streams that are difficult to access.

Risk

Fish Species

Habitat risk as a function of watershed condition and redundancy for perennial stream miles in the San Carlos, Middle Gila, and Agua Fria subbasins is high due to under representation and low redundancy on the national forest portion of the subbasins (see Perennial Streams in Watershed Condition Risk Assessment). The risk rating for perennial streams is low on the Upper Salt, Tonto, and Lower Verde subbasins due to similar conditions in the portion outside Tonto in these subbasins (99 percent of the Tonto subbasin lies within the Tonto National Forest) as on the national forest portions. Finally, the risk rating for perennial streams in the Lower Salt subbasin is high due to the high percentage of perennial streams on the Tonto.

Considering habitat occupied by nonnative species, departure from reference conditions is high across all historically occupied watersheds on the Tonto National Forest (table 97); although this has been mediated somewhat through recovery work that includes installation of barriers to nonnative fish and reintroduction projects. Risk to native fish species' viability due to threats from presence of nonnative species (competition, predation, disease) is therefore also high in all watersheds historically occupied on the Tonto. Nonnative fish species currently inhabit 561 miles (84 percent) of the 670 miles of reference perennial 4th-level watershed streams at the plan scale (table 97). Reaches that contain only native fish comprise 109 miles (16 percent) of the perennial streams in the plan area, of which, 14 miles (13 percent) are in Fossil Creek. In general, reaches containing only native fish are confined to headwater areas, often protected by a barrier (manmade or nature) preventing the encroachment of nonnative fish. There are manmade fish barriers in Arnett, Fossil, and Lime Creeks on the Tonto National Forest.

Table 97. Departure of streams from reference conditions (native fish only) on the Tonto National Forest by subbasin.

Subbasin Name	Reference Perennial Stream Miles	Current Native Fish Only Stream Miles	Current Native/ Nonnative Fish Stream Miles	% Departure of Current Native Only from Reference Stream Miles[1]	Risk Ranking*
San Carlos	0	0	0	0	Low
Middle Gila	72	4	68	94	High
Upper Salt	198	23	175	88	High
Tonto	112	28	84	75	High
Lower Salt	16	0	16	100	High
Lower Verde	240	46	194	81	High
Agua Fria	32	8	24	75	High

* 0 to 33 percent departure = low (L) risk ranking; 34 to 66 percent = moderate (M) risk ranking; 67 to 100 percent = high (H) risk ranking

Other Aquatic Biota

The Tonto National Forest is home to variety of amphibians, macroinvertebrate species, and riparian-dependent reptiles, such as narrow-headed and Northern Mexican gartersnakes. Because of their dependence on functioning riparian areas and perennial waters, viability of these species, like fish species, is linked to conditions of perennial streams (discussed above). Thus many of their populations on the Tonto National Forest are under high risk resulting in Federal protection status, State of Arizona species of greatest conservation need status, or both (AGFD 2012).

Aquatic macroinvertebrate sampling conducted by the Arizona Division of Enviromental Quality under the water quality monitoring program can assist in future determinations of ecological trends for perennial streams and should be included in monitoring plans (further discussed in “Water Quality”). Additional threats to Tonto National Forest sensitive aquatic species are discussed in the “At-risk Species” section.

Projections and Trends

Constructed waters are generally managed for beneficial uses under which constructions was authorized and often do not preserve historic ecological conditions that benefit native species (that is, normative hydrographs, water temperatures, nutrient and sediment loads). Baseline conditions for native biota species are already altered from historic conditions on these areas of the Tonto National Forest. Increasing human populations will continue to put pressure on water resources and alter flow regimes through ground water pumping, surface water irrigation, and increased drinking water demands within and outside Tonto National Forest boundaries.

Numerous efforts have occurred, are underway, or are being planned to expand the range of native fish species within the plan area. These include renovation and reintroduction of native species (in Fossil Creek), native fish reintroductions to fishless streams and springs (in Ash Creek, Dude Creek, Arnett Creek, Walnut Springs, and Roundtree Creek), and mechanical stressor removals of nonnative fish and crayfish. Overall, native fish populations are on an upward trend. New populations of headwater chub have been found in previously unknown locations. Conservation efforts on streams like Fossil, Dude, Ash, and Lime Creeks have greatly increased the number of miles of native species’ only streams on the Tonto. Efforts planned for Haigler Creek in the next couple of years as well as other efforts planned for the next 5 years should further increase the miles of native-species-only streams.

Water Yield

Water yield refers to the volume of surface water and groundwater generated within the planning unit available for use (for both ecosystem sustainability and human purposes) on and outside the Tonto National Forest. Surface water generated on the Tonto National Forest and available for export off the Tonto is essentially the difference between precipitation and a combination of evaporation and groundwater recharge. Some groundwater discharge is also available for export from the Tonto National Forest. The estimated water yield from the Tonto was approximately 350,000 acre-feet per year in the analysis of the management situation prepared in 1982 for the current forest plan (USDA Forest Service 1982). This estimate was based on U.S. Geological Survey gaging station records and runoff coefficients for vegetation types on the Tonto. This section will discuss precipitation, surface water, and groundwater conditions on the Tonto.

Precipitation

Context Area

Precipitation to the northwest and east of the Tonto National Forest boundary is similar to that found within the Tonto National Forest and is dominated by the mountainous topography of the central highlands transition zone between the Colorado Plateau to the north and the Basin and Range topography to the south. Precipitation varies with elevation. Areas of higher precipitation can be found in the Bradshaw Mountains on the Prescott National Forest, the rim country on the Coconino National Forest to the north, and the mountainous topography found on the Fort Apache Reservation to the east. The context area to the southwest of the Tonto National Forest is dominated by the Salt River and Gila River valleys where the Phoenix metropolitan area and agricultural areas between Casa Grande, Phoenix, and Florence can be found. Precipitation in these lower elevation areas is substantially less than within the Tonto National Forest. Precipitation averages less than 12 inches per year in most of the area to the southwest of the Tonto. Figure 58 displays average annual precipitation contours within the context area.

Planning Unit

Precipitation ranges from about 9 inches annually in the lowest elevations of the Tonto National Forest to more than 32 inches along the Mogollon Rim, Pinal Mountains, and Sierra Ancha Mountains. Average precipitation across the Tonto is approximately 18 to 20 inches annually. Precipitation typically occurs during two seasons. During winter, precipitation is derived from frontal systems that move from west to east across the state. Approximately 40 percent of the annual precipitation occurs from December to March as rain or snow from these systems. Moist air masses that encounter the Mogollon Rim escarpment are lifted and cooled, which condenses water vapor and enhances precipitation (ADWR 2009). Winter precipitation stored as snow is important for the water-dependent resources and cultural uses on and outside the Tonto.

During the summer monsoon season, atmospheric circulation shifts and brings moisture from the south and east. Rainfall during this season is driven primarily by convection (heat-driven upward motion), aided by topography, which forces air parcels upward to heights where water vapor condenses (ADWR 2009). Summer thunderstorms (convective storms) occur as spatially scattered cells of much smaller areal extent and duration but often of higher rainfall intensity than winter frontal storms. The Tonto National Forest receives approximately 35 percent of its annual rainfall from July to September from primarily convective type storms. August is typically the wettest month and June typically the driest. Average annual distribution of precipitation is displayed in figure 58. Remnants of tropical storms from the Gulf of Mexico can produce large storms during September and October. Precipitation on the Tonto National Forest can be affected by the El Niño phenomenon, which results from warmer than average ocean temperatures in the equatorial Pacific Ocean. El Niño conditions can result in greater than normal winter precipitation on the Tonto. In contrast, precipitation during La Niña conditions, resulting from cooler than average sea temperatures in the equatorial Pacific, are generally below normal and can result in regional droughts (Webb et al. 2007).

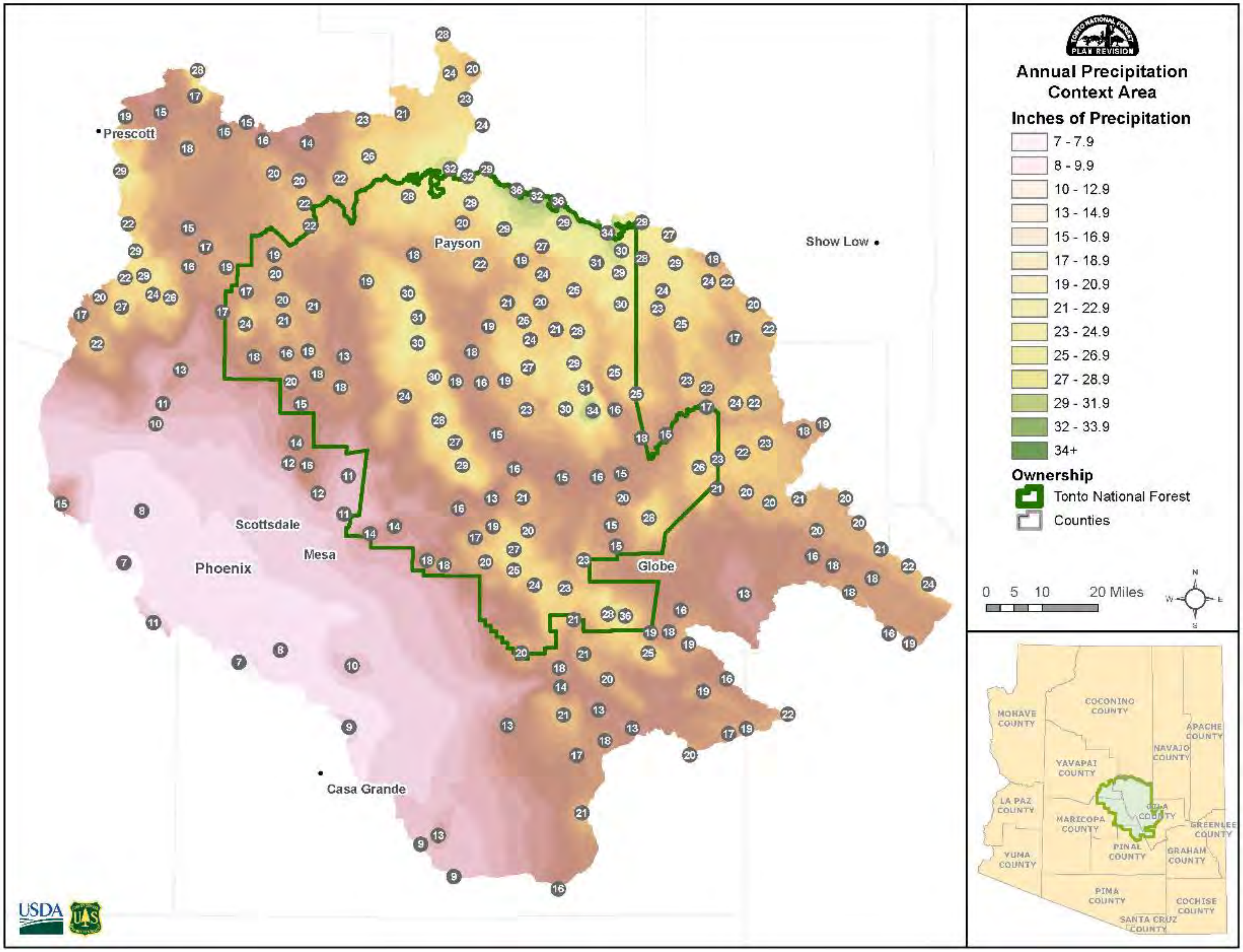


Figure 58. Annual precipitation in the context area

Arizona is divided into climate divisions that represent areas of relatively homogenous climate conditions in the state. Average monthly distribution of precipitation in the climate divisions is displayed in figure 59. Portions of three of the climate divisions occur within the Tonto National Forest. The distribution of these divisions are displayed in figure 60. Climate Division 3 lies within the Yavapai County portion, Climate Division 4 within the Gila County portion, and Climate Division 6 within the Maricopa and Pinal County portions of the Tonto National Forest.

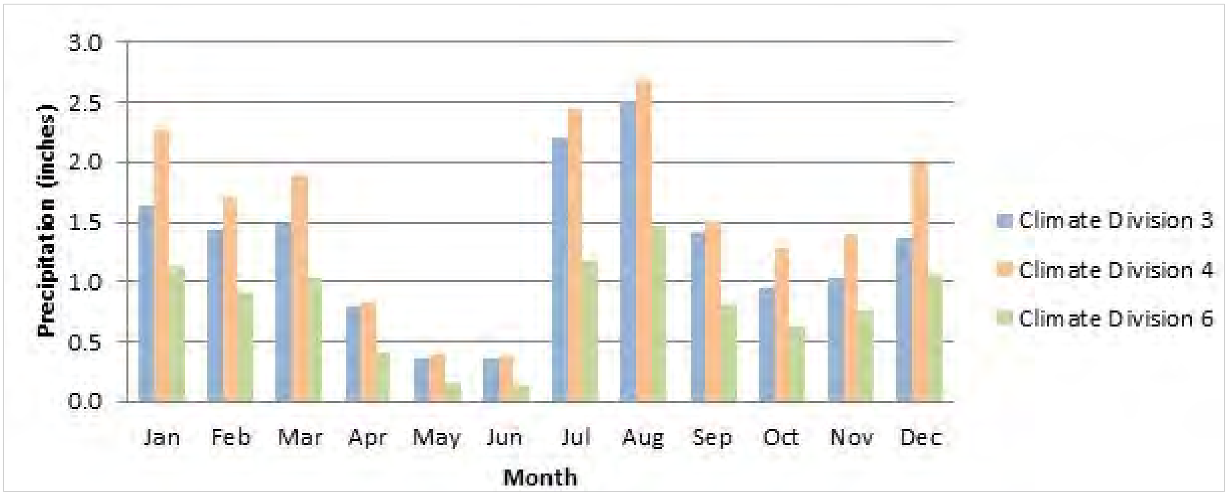


Figure 59. Average monthly precipitation by climate division, 1895 – 2013 (source: Western Regional Climate Center website 2015a)

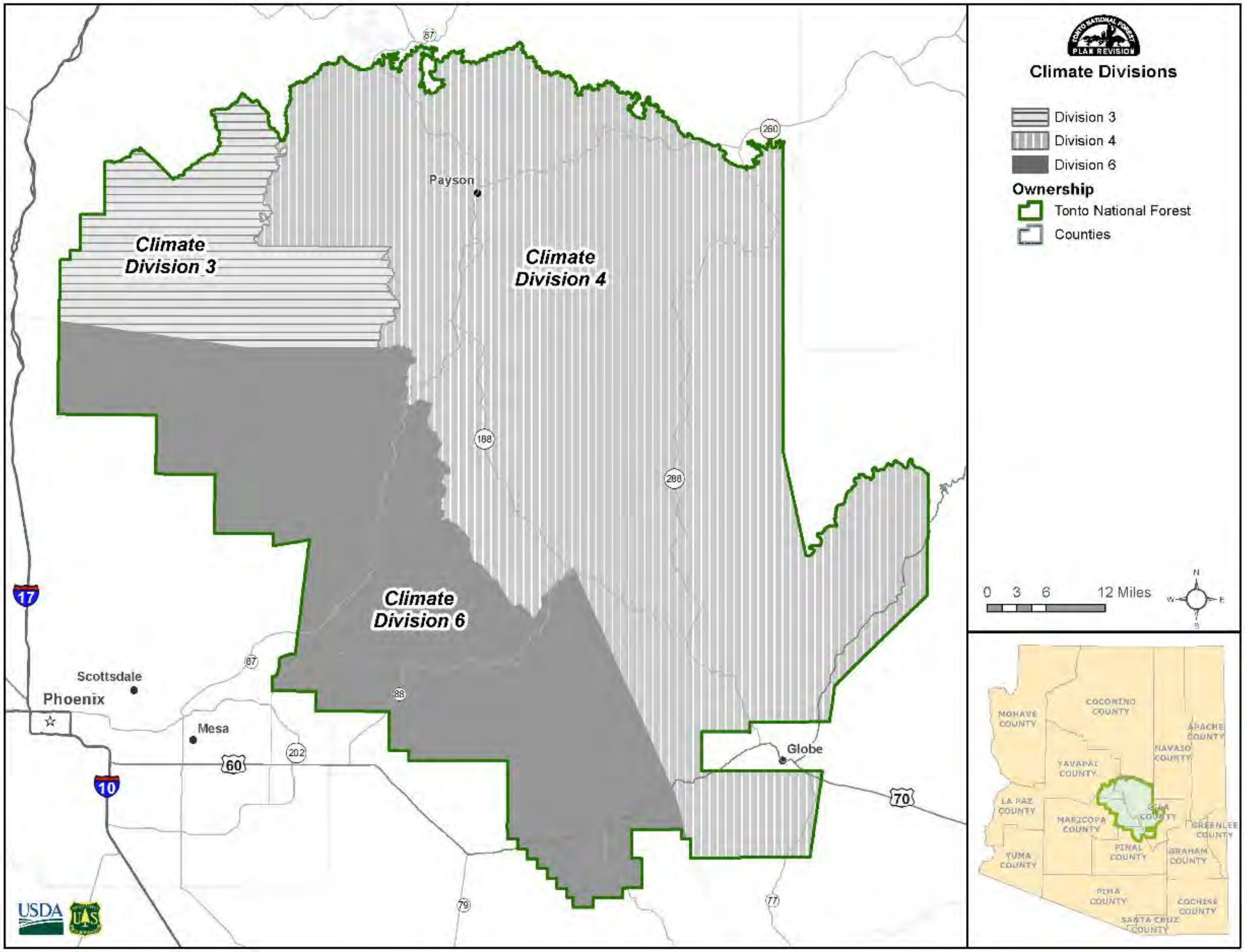


Figure 60. Climate divisions on the Tonto National Forest

Figure 61 displays annual precipitation for Climate Division 4 (Gila County). Precipitation ranges from 7 inches in 2002 to 40 inches in 1905, almost a six-fold difference in annual precipitation.

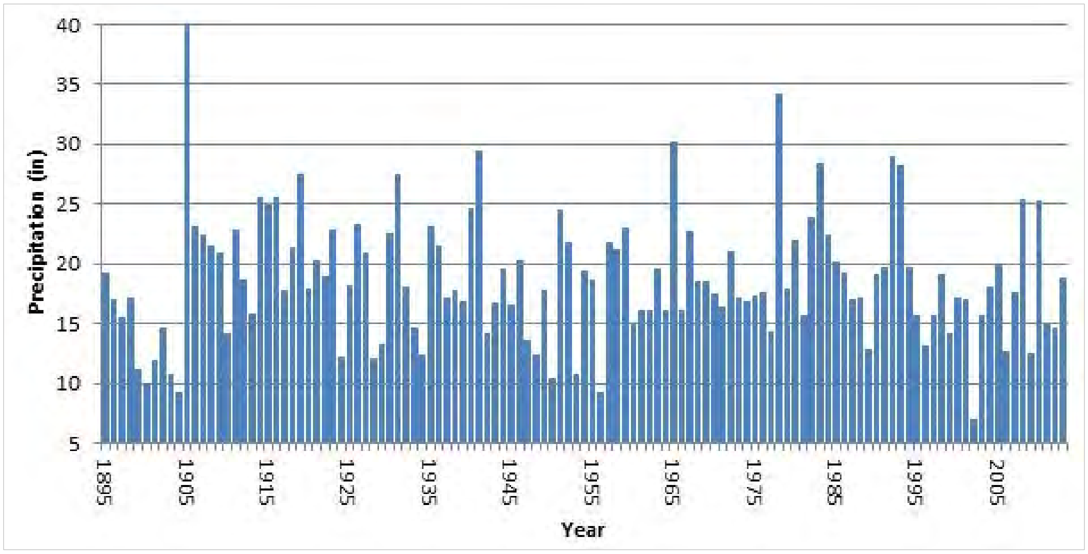


Figure 61. Annual precipitation for climate division 4 (source: Western Regional Climate Center website 2015a)

Precipitation distribution on the Tonto National Forest is influenced by elevation. Precipitation increases with elevation due to orographic lifting by the mountain ranges on the Tonto. Figure 62 plots relationship of precipitation to elevation based on weather station data within the Tonto National Forest. The uppermost point on the plot is precipitation data from the Tonto Fish Hatchery at the base of the Mogollon Rim. The abruptness of the terrain at the Mogollon rim compounds the effect of orographic lifting and results in even greater rainfall than would be expected from elevation alone. Average annual precipitation across the Tonto is displayed in figure 63.

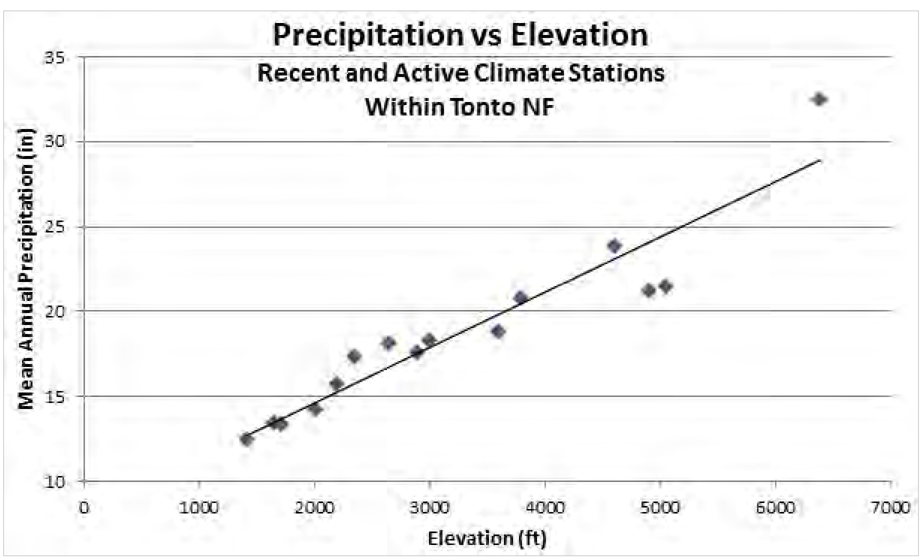


Figure 62. Effect of elevation on average annual precipitation (source: Western Regional Climate Center website 2015b)

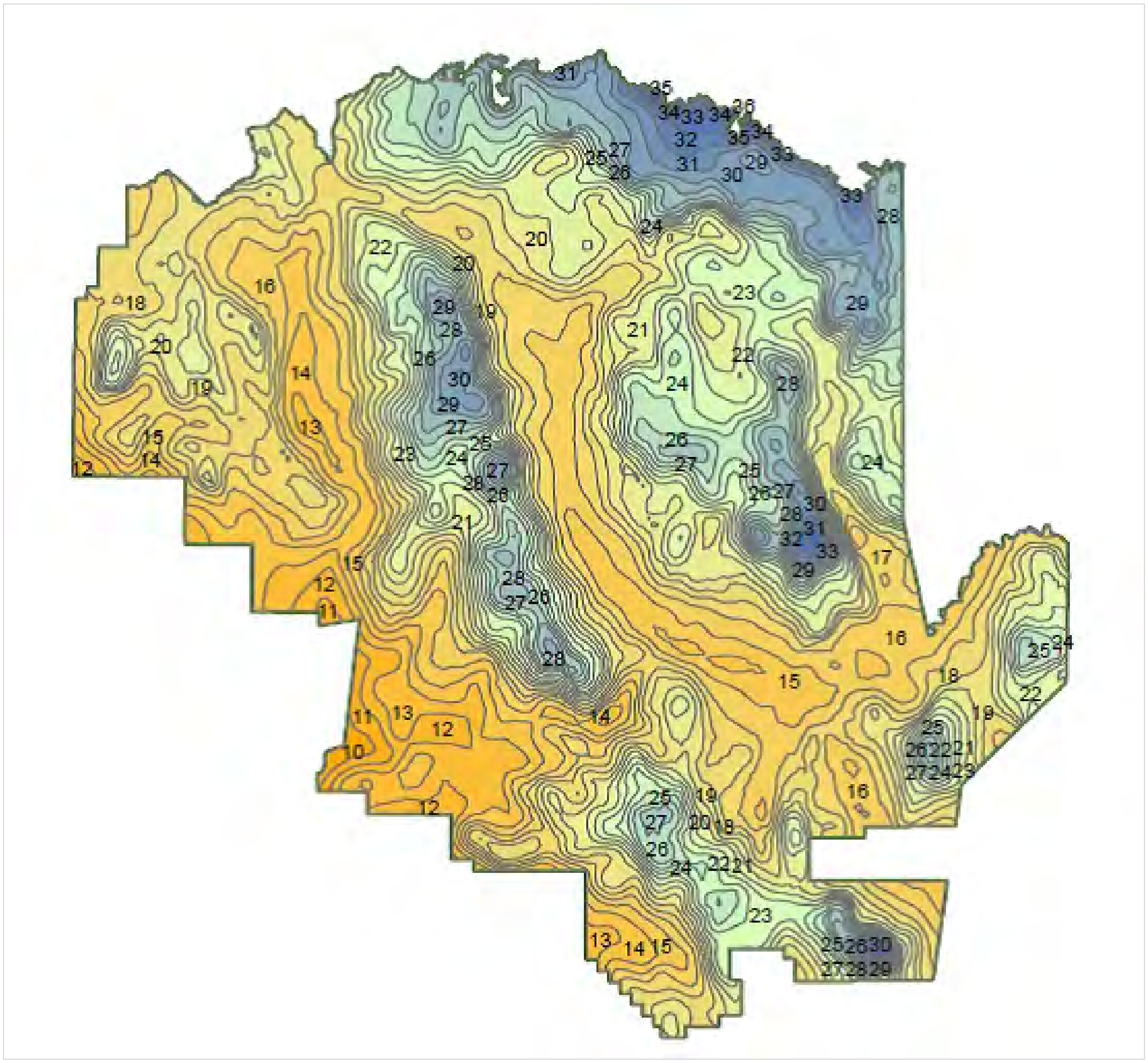


Figure 63. Tonto National Forest average annual precipitation (inches) (source: Oregon State University, 2014)

Table 98 and table 99 displays the average annual precipitation for Tonto National Forest portions of subbasins and watersheds as well as the subbasin and watershed averages. These are derived from the PRISM (Parameter-elevation Regressions on Independent Slopes) model database using the time period of 1981 to 2010 (Oregon State University 2014).

Watershed runoff from precipitation ranges from more than 5 inches along the base of the Mogollon Rim to less than one inch in the western and southern desert areas of the Tonto. Overall, runoff averages about 1.5 inches per year.

Table 98. Subbasin precipitation

Subbasin Name	Subbasin Area (square miles)	Tonto NF (square miles)	Tonto NF % of Subbasin	Average Annual Precipitation in Subbasin (inches)	Average Annual Precipitation in Tonto NF (inches)	% of Total on Tonto NF
San Carlos	1,075.2	98	9.1 %	17.1	20.2	10.8 %
Middle Gila	3,325.6	260	7.8 %	12.6	18.9	11.8 %
Upper Salt	2,152.5	1,197	55.6 %	20.9	20.6	54.9 %
Tonto	1,047.8	1,038	99.1 %	22.3	22.1	98.5 %
Lower Salt	997.2	457	45.8 %	12.8	16.6	59.7 %
Lower Verde	1,965.2	1,297	66.0 %	20.1	20.1	65.9 %
Aqua Fria	2,766.1	286	10.3 %	14.6	17.7	12.6 %

Source: Oregon State University 2014

Table 99. Average annual precipitation in each watershed

Watershed Name	Watershed Area (square miles)	Tonto NF % of Watershed	Average Annual Precipitation in Watershed (inches)	Average Annual Precipitation in Tonto NF (inches)	% of Total on Tonto NF
Sevenmile Wash-Sycamore Creek	252.9	23.1%	18.1	21.2	27.1%
Gilson Wash	245.4	16.2%	16.3	18.7	18.6%
Dripping Springs Wash-Gila River	392.7	1.3%	17.3	27.9	2.0%
Mineral Creek-Gila River	258.9	21.3%	18.0	22.9	27.1%
Box O Wash-Gila River	298.0	1.5%	15.8	18.9	1.8%
Upper Queen Creek	143.3	99.4%	18.0	18.0	99.5%
Paisano Wash-Gila River	373.6	0.4%	10.9	17.6	0.7%
Middle Queen Creek	378.0	13.0%	11.1	16.4	19.2%
Lower Queen Creek	156.9	1.3%	9.6	14.2	1.9%
Sawmill Creek-Salt River	266.8	6.2%	20.7	21.3	6.4%
Canyon Creek	317.6	20.6%	23.9	25.7	22.2%
Cherry Creek	278.2	95.3%	22.6	22.7	95.8%
Salt River Draw-Salt River	236.3	55.8%	19.7	19.3	54.8%
Pinal Creek	199.7	77.5%	18.7	19.3	79.9%
Pinto Creek	186.0	100.0%	19.4	19.4	100.0%
Salome Creek	118.7	100.0%	23.8	23.8	100.0%
Salt River-Theodore Roosevelt Lake	259.1	100.0%	18.0	18.0	100.0%
Spring Creek	146.7	100.0%	23.4	23.4	100.0%
Haigler Creek-Tonto Creek	224.0	95.5%	27.9	27.6	94.4%
Rye Creek-Tonto Creek	300.9	100.0%	20.4	20.4	100.0%
Gun Creek-Tonto Creek	283.0	100.0%	20.5	20.5	100.0%

Watershed Name	Watershed Area (square miles)	Tonto NF % of Watershed	Average Annual Precipitation in Watershed (inches)	Average Annual Precipitation in Tonto NF (inches)	% of Total on Tonto NF
Tonto Creek-Theodore Roosevelt Lake	93.1	100.0%	18.2	18.2	100.0%
Salt River-Apache, Canyon, and Saguaro Lake	388.4	100.0%	17.4	17.4	100.0%
Indian Bend Wash	220.8	0.4%	10.5	14.0	0.6%
Salt River below Saguaro Lake	388.0	17.5%	9.4	12.1	22.5%
East Verde River	331.3	95.8%	24.5	24.3	94.7%
Fossil Creek-Verde River	299.2	20.8%	20.8	22.7	22.8%
Tangle Creek-Verde River	277.6	100.0%	18.6	18.6	100.0%
Verde River-Horseshoe and Bartlett Reservoir	300.2	100.0%	18.8	18.8	100.0%
Sycamore Creek	192.6	98.7%	20.3	20.4	99.3%
Camp Creek-Verde River	266.3	56.3%	13.6	14.8	61.6%
Sycamore Creek-Agua Fria River	365.8	28.6%	18.2	18.5	29.1%
Agua Fria River-Lake Pleasant	371.8	3.1%	17.7	18.7	3.2%
Cave Creek-Arizona Canal Diversion Channel	285.2	31.1%	12.3	16.8	42.2%
New River	363.3	22.5%	11.8	17.5	33.3%

Source: Oregon State University 2014

Streamflow

Context Area

See "Watershed Extent and Perennial Streams" section for a discussion of perennial streams in the context area. Major perennial streams in the context area beyond the boundaries of the Tonto National Forest are displayed in figure 31 on page 187 and listed in table 100.

Table 100. Major perennial streams within the context area

Subbasin Name	Major Perennial Streams	Miles
San Carlos	Blue River San Carlos River	12.6 23.5
Middle Gila	Gila River	86.9
Upper Salt	Canyon Creek Cibecue Creek Salt River	42.8 36.2 25.0
Lower Salt	Salt River	7.1
Lower Verde	Verde River West Clear Creek	44.8 37.3
Agua Fria	Agua Fria River	16.5

Density of perennial streams within the Tonto National Forest is about twice as high as it is in the context area outside the Tonto. This may be due to lower average precipitation in parts of the context area, potentially greater channel transmission losses in the broad alluvial valleys in parts of the context area, and stream diversions from the Gila, Salt, and Agua Fria Rivers that shorten the length of perennial flow on major rivers in the context area.

There are approximately 50 current and historic U.S. Geological Survey stream gages in the context area outside the Tonto National Forest boundaries. Many of these gages record flow in regulated stream reaches affected by dams, diversions, and flood control structures. Three gages in the Lower Verde subbasin are located on unregulated stream reaches above the Tonto National Forest: two on the mainstem of the Verde River and one on West Clear Creek. There are 10 gages on unregulated tributaries to the mainstem of the Agua Fria River in the Agua Fria subbasin. Flow in the Agua Fria River is captured in Lake Pleasant. Total water yield is estimated at approximately 350,000 acre-feet per year from the Tonto National Forest portion of the context area based on published water yield data from vegetation types found on the Tonto and from crude estimates of gaging station data on and near the Tonto. A crude estimate of water yield from the portion of the context area outside the Tonto is approximately 330,000 acre-feet per year from gaging station data located within and near the context area. As mentioned previously, several of the major rivers in the context area are affected by dams, diversions, and flood control structures making estimates of water yield difficult.

Planning Unit

The Tonto National Forest contains diverse topography and a large elevational range, resulting in diverse vegetation types and ecosystems. Topography varies from desert basins in the lower reaches of the Verde and Queen Creek watersheds to deeply incised canyons along the Mogollon Rim and high mountain peaks. Because of the high elevations and associated higher rainfall and snowfall, the Tonto contains a portion of the state's most important water-producing watersheds, the Salt and Verde Rivers (ADWR 2009). These watersheds contain the greatest concentration of perennial streams found in the state, which in turn support extensive riparian habitat (ADWR 2009).

Streamflow is composed of both base flow and surface runoff. Base flow originates from groundwater that discharges as springs from aquifers and by groundwater discharged directly from the bed and banks of stream channels. Base flow maintains streamflow throughout the year in perennial streams and is particularly important for maintaining flow during the dry periods of the year. Surface runoff is the result of rain storms and snowmelt. Surface flows vary with precipitation but can have greater variability than precipitation. Figure 64 illustrates the variability in streamflow in Tonto Creek. This figure includes data from the Tonto Creek near Roosevelt stream gage from 1914 to 1940 and the Tonto Creek above Gun Creek gage from 1941 to 2013. Average annual discharge varies from a minimum of 14.3 cubic feet per second in 2012 to 648 cubic feet per second in 1978, a 45-fold increase from the minimum flow.

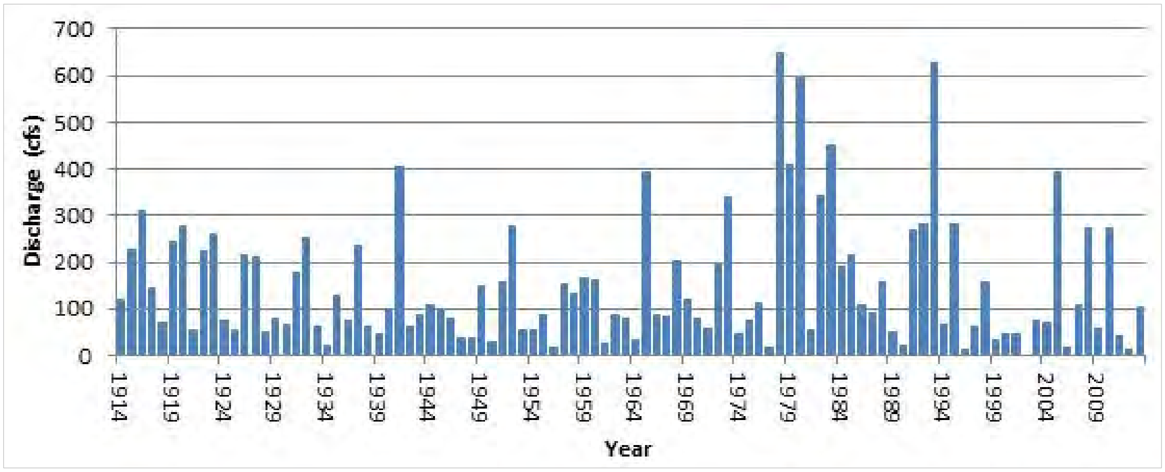


Figure 64. Annual average stream flow for Tonto Creek in cubic feet per second (cfs)
(data from USGS stream gage: Tonto Creek near Roosevelt –gage number 09499500 from 1914 to 1940 and Tonto Creek above Gun Creek, Near Roosevelt, Az. – gage number 09499000 from 1941 to 2013)
Source: USGS, 2014b

Base flow has much less variability than surface runoff and constitutes a relatively small proportion of annual streamflow for the majority of the watersheds on the Tonto National Forest. Exceptions include Fossil Creek on the border between the Tonto and Coconino National Forests and Pinal Creek in the Globe Ranger District. Base flows in Fossil Creek are dominated by discharge from springs forming the Fossil Springs complex of springs. Discharge from these springs averages about 46 cubic feet per second and provides about 74 percent of the total basin water yield from the watershed area above the springs (NAU 2005). Spring flow provides greater than 90 percent of the flow in the creek during the summer months. Base flows from Fossil Creek increase flow in the Verde River by almost 50 percent (based on median monthly flows at the Camp Verde gage on the Verde River) during the low flow season from May through July. Mean monthly flows in Fossil Creek are displayed in figure 65. This figure illustrates the contribution of base flows to the creek and the small relative difference between months dominated by surface runoff and those dominated by spring discharge.

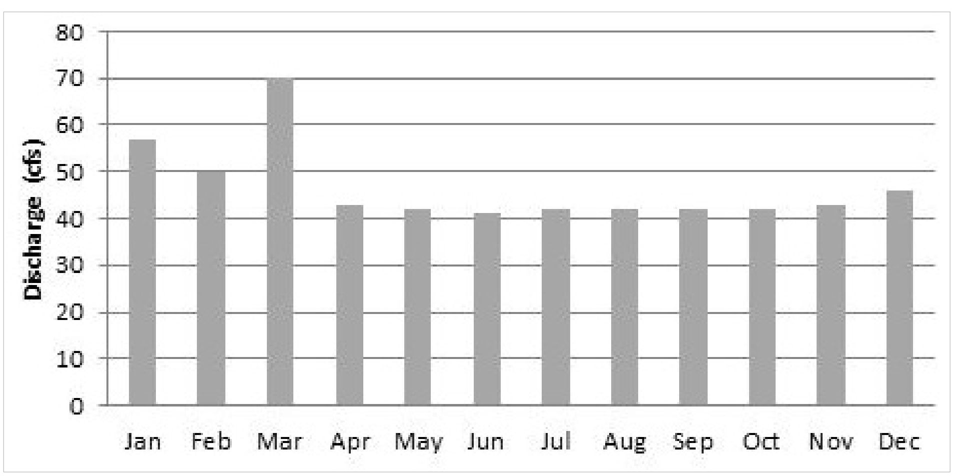


Figure 65. Mean monthly flow for Fossil Creek
(data from USGS stream gage Fossil Creek near Strawberry, AZ gage number 09507480, 2014)

Figure 66 illustrates stream flow conditions at a gage on Sycamore Creek (Sycamore Creek near Fort McDowell) where stream flows are dominated by surface runoff and base flows are not a significant component of stream flow. This figure illustrates the large difference between months with substantial surface runoff and those without, in contrast to the flow characteristics in Fossil Creek.

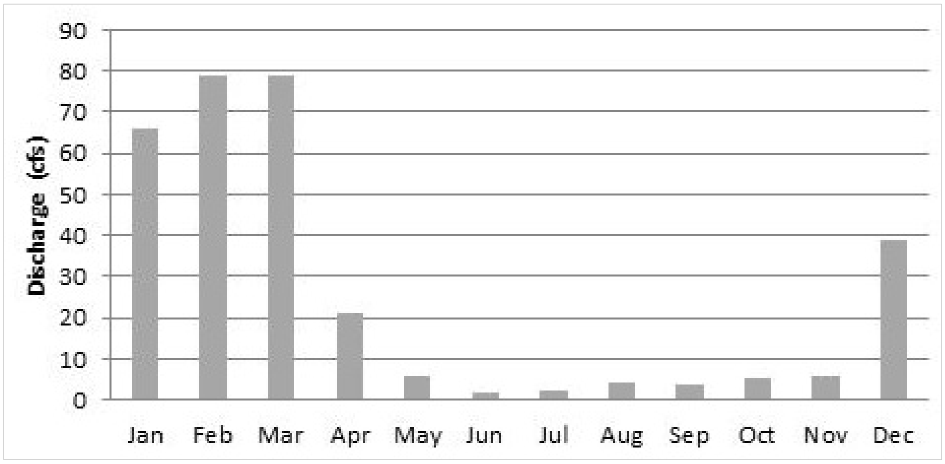


Figure 66. Mean monthly flow for Sycamore Creek at Fort McDowell
(data from USGS gaging station Sycamore Creek Near Fort McDowell, Az, gage Number 09510200) Source: USGS, 2014

This figure illustrates stream flow conditions typical of most streams on the Tonto National Forest where base flows are not major components of streamflow. It does illustrate the importance of groundwater discharge for maintaining perennial flow during the hottest part of the year and in the fall. May and June are typically the driest months of the year and although July and August are typically the months with the greatest rainfall, high evaporation rates during this period result in little runoff and only small contributions to streamflow. Summer rainfall typically occurs as high-intensity summer thunderstorms of limited areal extent. These storms can result in high peak flows (flash floods) in smaller drainages but do not release a sufficient volume of water to substantially affect larger drainages. Widespread winter frontal storms have lower rainfall intensity but are of longer duration and affect much larger areas than summer thunderstorms, resulting in greater runoff volumes and contributions to streamflow. Reduced evaporation rates during the winter also result in greater runoff volumes.

Table 101 and table 102 identify stream gages within and downstream from the Tonto on perennial and intermittent streams. The tables identify both current and historical gages.

Table 101. Stream gages on perennial streams within and downstream of Tonto National Forest (TNF)

Gage Name/Number	Drainage Area (square miles)	Percent of Watershed within Tonto NF	Period of Record	Subbasin/ Watersheds	Comment
Cherry Creek near Young (09497500)	62.1	Primarily within TNF	9/1963 – 9/1977	Upper Salt/Cherry Creek	None
Cherry Creek near Globe (09497980)	200	Primarily within TNF	6/1965 - present	Upper Salt/Cherry Creek	None
Pinal Creek at Inspiration Dam (09498400)	195	Primarily within TNF	7/1980 - Present	Upper Salt/Pinal Creek	None
Salt River near Roosevelt (9498500)	4,306	<20%	10/1913 - Present	Upper Salt/Salt River-Theodore Roosevelt Lake	None
Pinto Creek above Haunted Canyon near Miami (094985005)	16.95	Primarily within TNF	11/2007 - Present	Upper Salt/Pinto Creek	Monitoring Gage for Carlotta Copper Project
Pinto Creek Below Haunted Canyon near Miami (09498501	37.3	Primarily within TNF	10/95 - Present	Upper Salt/Pinto Creek	Monitoring Gage for Carlotta Copper Project. Affected by mining activities
Pinto Creek near Miami (09498502)	102	Primarily within TNF	9/1994 - Present	Upper Salt/Pinto Creek	Affected by mining activities
Tonto Creek near Gisela (09498800)	430	Primarily within TNF	12/1964 – 9/1975	Tonto/Rye Creek-Tonto Creek	None
Rye Creek near Gisela (09498870)	122	Primarily within TNF	1/1965 – 9/1985	Tonto/Rye Creek-Tonto Creek	None
Tonto Creek above Gun Creek, near Roosevelt (09499000)	675	Primarily within TNF	12/1940 - Present	Tonto/Gun Creek – Tonto Creek	None
Tonto Creek near Roosevelt (09499500)	841	Primarily within TNF	10/1913 – 12/1940	Tonto/Lambing Creek – Tonto Creek	None
Salt River below Stewart Mountain Dam (9502000)	6232	40%	10/1934 - Present	Lower Salt/Salt River below Saguaro Lake	Flow controlled by 4 upstream reservoirs
Fossil Creek Near Strawberry (09507480)	68.5	10%	10/2010 - present	Lower Verde/Fossil Creek-Verde River	None
East Verde River near Pine (09507600)	6.34	Primarily within TNF	10/1961 – 10-1971	Lower Verde/East Verde River	None
Webber Creek above W Fork Webber Creek near Pine (09507700)	4.79	Primarily within TNF	7/1959 – 9/1974	Lower Verde/East Verde River	Established for watershed research

Gage Name/Number	Drainage Area (square miles)	Percent of Watershed within Tonto NF	Period of Record	Subbasin/ Watersheds	Comment
Webber Creek below W Fork Webber Creek near Pine (09507900)	9.63	Primarily within TNF	7/1959 – 9/1965	Lower Verde/East Verde River	Established for watershed research
East Verde River near Childs (09507980)	328	Primarily within TNF	9/1961 - Present	Lower Verde/East Verde River	Flow augmented by imports from Blue Ridge Reservoir
Verde River below Tangle Creek, above Horseshoe Dam (9508500)	5,858	11%	8/1945 – Present	Lower Verde/ Tangle Creek-Verde River	None
Verde River below Bartlett Dam (09510000)	6,161	15%	1/1904 - Present	Lower Verde/Camp Creek – Verde River	Flow regulated by 2 dams. 1st dam constructed in 1939
Sycamore Creek near Sunflower (09510150)	52.3	Primarily within TNF	10/1961 – 9/1976	Lower Verde/ Sycamore Creek	None

Table 102. Stream gages on intermittent streams within and downstream of Tonto National Forest (TNF)

Gage Name/Number	Drainage Area (square miles)	Percent of Watershed within Tonto NF	Period of Record	Subbasin/ Watersheds	Comment
South Fork Parker Creek near Roosevelt (09498503)	1.09	Primarily within TNF	12/1985 - present	Upper Salt/Salt River – Theodore Roosevelt Lake	Established for watershed research
West Fork Webber Creek near Pine (09507800)	4.27	Primarily within TNF	7/1959 – 9/1965	Lower Verde/East Verde River	Established for watershed research
Wet Bottom Creek near Childs (09508300)	36.4	Primarily within TNF	7/1967 – Present	Lower Verde/ Tangle Creek—Verde River	National ambient water quality monitoring program site.
W Fork Sycamore Creek above McFarland Canyon near Sunflower (9510070)	4.6	Primarily within TNF	10/1966 – 5/1986	Lower Verde/ Sycamore Creek	Established for watershed research
West Fork Sycamore Creek near Sunflower (9510080)	9.8	Primarily within TNF	8/1961 – 9/1974	Lower Verde/ Sycamore Creek	Established for watershed research
East Fork Sycamore Creek near Sunflower (9510100)	4.5	Primarily within TNF	7/1961 – 5/1986	Lower Verde/ Sycamore Creek	Established for watershed research
Rock Creek Near Sunflower (9510180)	15.2	Primarily within TNF	3/1963 – 9/1972	Lower Verde/ Sycamore Creek	None

Gage Name/Number	Drainage Area (square miles)	Percent of Watershed within Tonto NF	Period of Record	Subbasin/ Watersheds	Comment
Sycamore Creek near Ft McDowell (09510200)	164	Primarily within TNF	10/1960 – Present	Lower Verde/ Sycamore Creek	None
Cave Creek below Cottonwood Creek near Cave Creek (9512280)	82.7	Primarily within TNF	10/1980 - Present	Agua Fria/Cave Creek – Arizona Canal Diversion Channel	None
New River near Rock Springs (9513780)	68.3	Primarily within TNF	10/1965 - Present	Agua Fria/New River	None
Queen Creek Below Whitlow Dam near Superior (9478500)	144	Primarily within TNF	5/1948 – Present	Middle Gila/Upper Queen Creek	Flow regulated by flood control dam

Annual water yield from each basin can vary by up to several orders of magnitude between years depending on amount and timing of precipitation, geology, or transmission losses. Streams with large base flow components have smaller variability than ephemeral streams where annual water yield is dependent entirely on rainfall or snowmelt. For example, the maximum annual water yield of the Verde River below Tangle Creek gage which has a substantial base flow component is only 12 times greater than the minimum annual yield (1946 to 2014) whereas the maximum annual yield of New River near Rock Springs (1966 to 2014) which has a small base flow component is almost 77,000 times greater than the minimum annual yield.

Groundwater

Context Area

The context area lies primarily within the Central Highlands and active management area planning areas established by the Arizona Department of Water Resources. A smaller portion, on the southeast side of the context area, lies within the Southeastern Arizona planning area. The percent of the context area occupied by each of the planning areas is displayed in table 103 below. The majority of the Tonto National Forest (83 percent) lies within the Central Highlands Planning Area. The area of the national forest within the Active Management Area Planning Area (13 percent of the Tonto) lies entirely within the Phoenix Active Management Area. The percent of the national forest occupied by each of the planning areas is displayed in table 103 as well. The relationship of the Arizona Department of Water Resources planning areas to the context area and national forest is displayed in figure 67.

Table 103. Percent context area occupied by each planning area

Planning Area Name	Acres within Context Area	Percent of Context Area	Acres within Tonto NF Planning Unit	Percent of Tonto NF Planning Unit
Central Highlands	4,173,235	49 %	2,470,869	83 %
Active Management Area	3,063,065	36 %	390,862	13 %
Southeastern Arizona	1,293,549	15 %	104,091	4 %

The Central Highlands planning area is located within the Central Highlands Transition Zone which is one of three main physiographic regions in the state. The Central Highlands Transition Zone is located between the Basin and Range Province of southern and western Arizona, which is characterized by long, broad alluvial valleys separated by north-south trending mountain ranges, and the Colorado Plateau Province to the north and east, which is characterized by sedimentary rocks that have eroded into canyons and plateaus (ADWR 2009). The Central Highlands Transition Zone is characterized by a relatively narrow band of mountains and most of the state's perennial streams. Groundwater is found in alluvial deposits, layered sedimentary rocks, thin alluvial deposits along major streams and fractured crystalline, sedimentary, and volcanic rocks.

The Central Highlands planning area occupies 8.9 million acres and includes most of central Arizona. The context area represents about 47 percent of the planning area and the Tonto National Forest represents about 28 percent of the planning area. The planning area is composed of five groundwater basins.

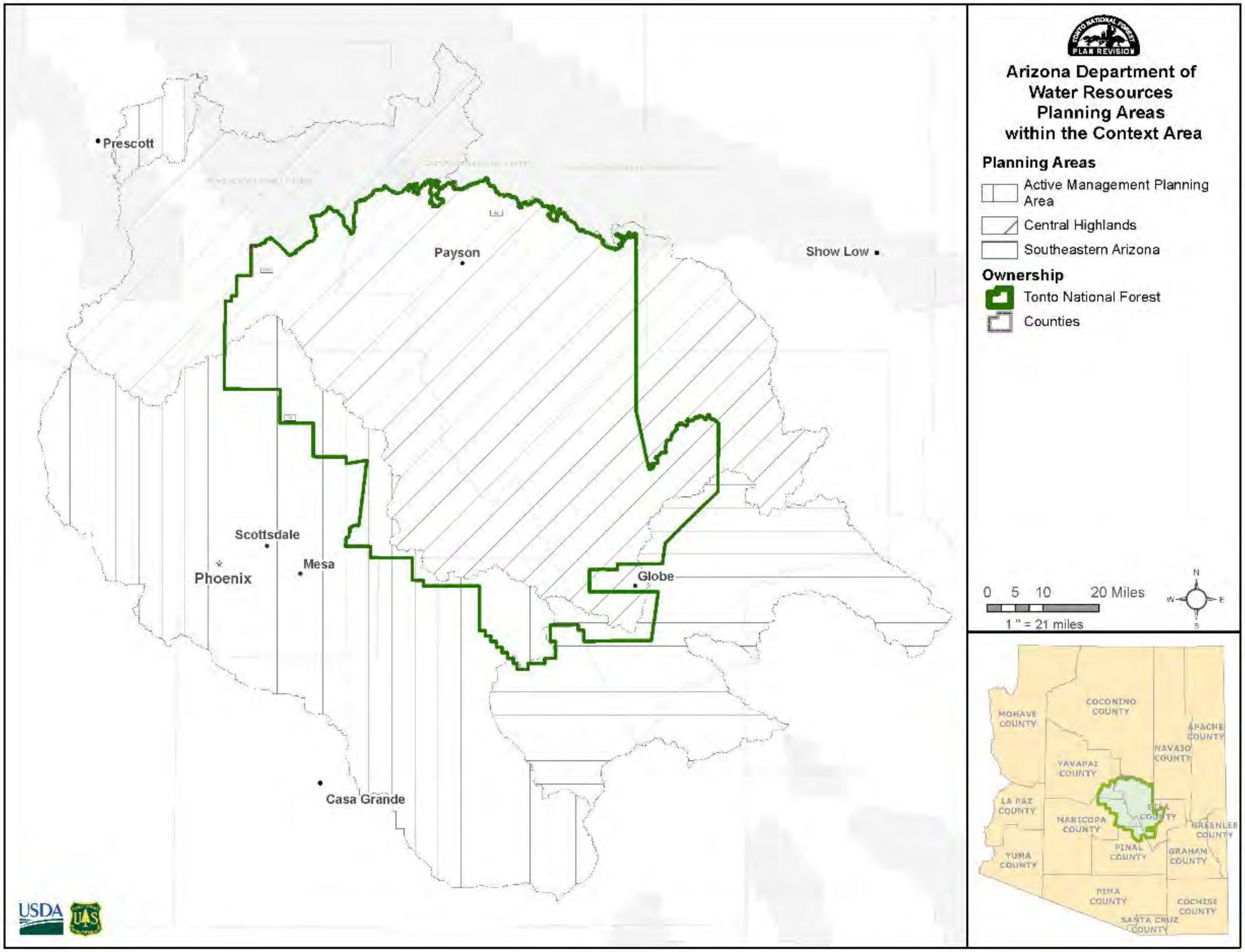


Figure 67. Arizona Department of Water Resources planning areas within the context area

The active management area planning area is composed of five active management areas. These are areas that relied heavily on mined groundwater prior to enactment of the 1980 Arizona groundwater code. This code was enacted to reduce over pumping of the states finite groundwater resources. In the Phoenix, Prescott, and Tucson active management areas, the primary management goal is to achieve safe yield by the year 2025. Safe yield is achieved when the amount of groundwater being withdrawn equals the amount that is annually replaced. The goal within the Pinal active management area is to allow development of nonirrigation uses and to preserve existing agricultural economies for as long as feasible. Within active management areas, groundwater rights were established; wells are regulated; and the municipal, industrial, and agricultural sectors are subject to mandatory conservation programs (ADWR 2010). Outside active management areas, which includes the majority of the Tonto National Forest, there is essentially no restriction on withdrawing groundwater as long as it is put to reasonable and beneficial use (ADWR 2010).

The majority of the context area within the active management area planning area lies within the Phoenix active management area. The portion of the Tonto National Forest within the active management area planning area lies entirely within the Phoenix active management area. Table 104 displays the percent of the four active management areas within the active management area planning area portion of the context area.

Table 104. Percent of the four active management areas within the active management area planning area

Active Management Area (AMA) Planning Area	Acres within Context Area	Percent of Active Management Area Portion of Context Area
Phoenix AMA	2,205,099	72 %
Pinal AMA	466,305	15 %
Prescott AMA	110,391	4 %
Tucson AMA	281,310	9 %

The active management area and southeastern Arizona (15 percent of context area and 4 percent of Tonto National Forest) planning areas are primarily located within the Basin and Range physiographic region. This region contains thick productive basin fill deposits between the mountain ranges characterizing this province. The basins are characterized by relatively small to moderate amounts of mountain front recharge and streamflow infiltration (ADWR 2010). Several groundwater basins exist within each of the planning areas. The extent of each of the groundwater basins within the context area and Tonto National Forest are displayed in figure 68 and listed in table 105.

From table 105, it is evident the Tonto National Forest is not a significant contributor to groundwater conditions in any of the groundwater basins in the southeastern Arizona planning area. The Tonto represents less than 5 percent of the area of any of the groundwater basins lying within or partly within its boundaries. Selected aquifer characteristics of the major groundwater basins represented on the Tonto are displayed in table 106.

Table 105. Groundwater basin extent

Basin Name	Basin Area (acres)	Context Area within Basin (acres)	Percent of Basin	Tonto NF Area within Basin (acres)	Percent of Basin
Central Highlands Groundwater Basins					
Verde River	3,623,379	1,069,040	29.5%	717,621	19.8%
Agua Fria	808,401	808,157	100.0%	74,370	9.2%
Tonto Creek	611,448	610,666	99.9%	604,676	98.9%
Salt River	3,348,260	1,685,247	50.3%	1,074,202	32.1%
Upper Hassayampa	503,766	124	0.0%	0	0
Active Management Area Groundwater Basins					
Prescott	30,7475	1,10391	35.9%	0	0
Phoenix	344,7122	2,205,059	64.0%	390,862	11.3%
Pinal	262,1140	466,305	17.8%	0	0
Tucson	247,5877	381,310	15.4%	0	0
Southeastern Arizona Groundwater Basins					
Morenci	1,023,644	253	0.0%	0	0
Safford	3,038,294	600,926	19.8%	62,703	2.1%
Bonita Creek	292,198	88,706	30.4%	0	0
Lower San Pedro	1,039,387	174,963	16.8%	35,371	3.4%
Dripping Springs Wash	242,238	240,898	99.4%	3,173	1.3%
Donnelly Wash	187,657	187,591	100.0%	2,845	1.5%

Table 106. Selected characteristics of major groundwater basins

Basin	Major Aquifers	Estimated Natural Recharge (acre-feet per year)	Estimated Water in Storage[2] (million acre-feet)
Agua Fria	Basin fill and sedimentary rock.	9,000	0.6
Salt River	Recent stream alluvium and sedimentary rock (Gila Conglomerate and C and R Aquifers).[1]	178,000	>8.7
Tonto Creek	Basin fill and sedimentary rock (C and R Aquifers).	17,000 -37,000	2 to 9.4
Verde River	Recent stream alluvium, basin fill interbedded with volcanic rock, sedimentary rock (Verde Formation and C and R aquifers) and igneous and metamorphic rocks.	107,000 to >148,000	13 to 28
Phoenix Active Management Area	Recent alluvium, basin fill with and without interbedded basalt, and sedimentary rock (conglomerate).	24,100	80.4 (to 1,000ft)

1. C aquifer is the Coconino Sandstone and the R aquifer is the Redwall Limestone both of which underlie the Colorado Plateau.
2. Estimate of water in storage is to a depth of 1,200 feet unless otherwise noted.

Source: ADWR 2009

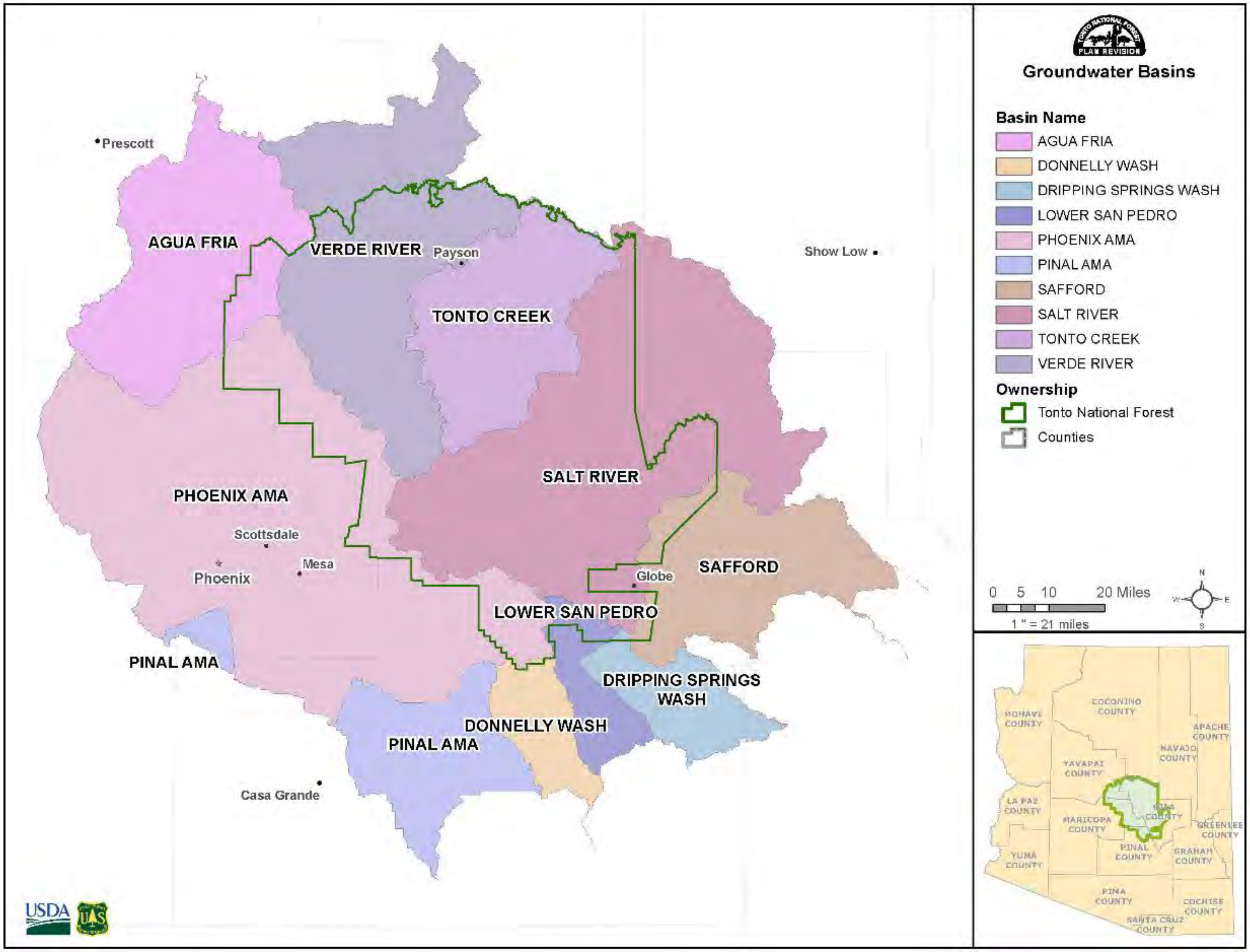


Figure 68. Location of groundwater basins

Planning Unit

Much of the Tonto National Forest is characterized by a band of mountains consisting of igneous, metamorphic, and sedimentary rocks. High elevations, steep topography, and extensive bedrock result in relatively high runoff and small water storage capabilities in much of the Tonto as compared to alluvial basins in the southern part of the state. A unique geographic feature of the Tonto National Forest is the Mogollon Rim, an escarpment that defines the southern boundary of the Colorado Plateau. The rim is approximately 7,000 feet in elevation with sheer drops of 2,000 feet at some locations (ADWR 2010). The rim stretches for over a hundred miles and forms much of the northern boundary of the Tonto.

Groundwater within the Tonto National Forest occurs primarily within fractured bedrock and in shallow alluvial aquifers along the margins of streams. Deeper basin fill aquifers with greater groundwater resources although limited in areal extent on the Tonto can also be valuable groundwater resources for cultural uses. They are typically hydrologically connected with stream alluvium. Basin-fill aquifers underlie the area around Globe, Tonto Basin, the Salt River Reservoirs, Pinto Valley west of Miami, Cherry Creek, areas bordering the Verde River, Sycamore Creek (tributary to the Verde River at Fort McDowell), Queen Creek, and Cave Creek. Along the Salt River and around Roosevelt Lake, the basin fill is up to 2,000 feet thick (ADWR 2009). Recharge to basin-fill aquifers occurs primarily along mountain fronts and by infiltration from streams.

Groundwater recharge occurs in areas of higher precipitation, particularly along the Mogollon Rim just north of the Tonto National Forest boundary, the Sierra Ancha Mountains northeast of Roosevelt Lake, the Pinal Mountains south of Globe-Miami, and the Mazatzal Mountains between the Verde River and Tonto Basin (figure 69). Precipitation at the highest elevations of these features averages greater than 30 inches annually. Groundwater recharge on the Mogollon Rim was estimated to be 4 to 17 percent (up to 5 inches) of the annual precipitation on the Rim (Parker et al. 2005). Groundwater discharging from the Coconino Sandstone (also known as the C Aquifer) and the Redwall Limestone at the base of the Rim maintains perennial flow in many of the streams that originate beneath the Rim. Several of these streams maintain perennial flow for only a mile or two before flow is lost due to seepage into permeable and occasionally karstic terrain. Examples include Webber, Chase, Dude, Bonita, Ellison, and Horton Creeks. The largest spring discharging from below the Rim is Fossil Springs which discharges at an estimate 42 to 45 cubic feet per second and maintains perennial flow in Fossil Creek. The Fossil Springs complex of springs are the largest springs in Arizona outside the Grand Canyon. Other major springs discharging below the Mogollon Rim include Tonto Spring that flows into Tonto Creek, See Spring that flows into Christopher Creek, and OW Springs that flow to Canyon Creek. Figure 69 displays a schematic of groundwater recharge and discharge from the Mogollon Rim along the northern boundary of much of the Tonto National Forest.

Groundwater recharge in the Sierra Ancha Mountains discharges to a number of springs on the east side of the mountains that help to sustain perennial flow in Cherry Creek. Perennial flow in Workman and Reynolds Creeks that flow to the west side of the mountains, Coon Creek on the south side and Spring and Rock Creeks on the north side are also sustained by groundwater discharged from precipitation recharged in the Sierra Ancha Mountains. Groundwater discharging from the west side of the Mazatzal Mountains sustains perennial flow in a number of streams draining through the Mazatzal Wilderness to the Verde River.

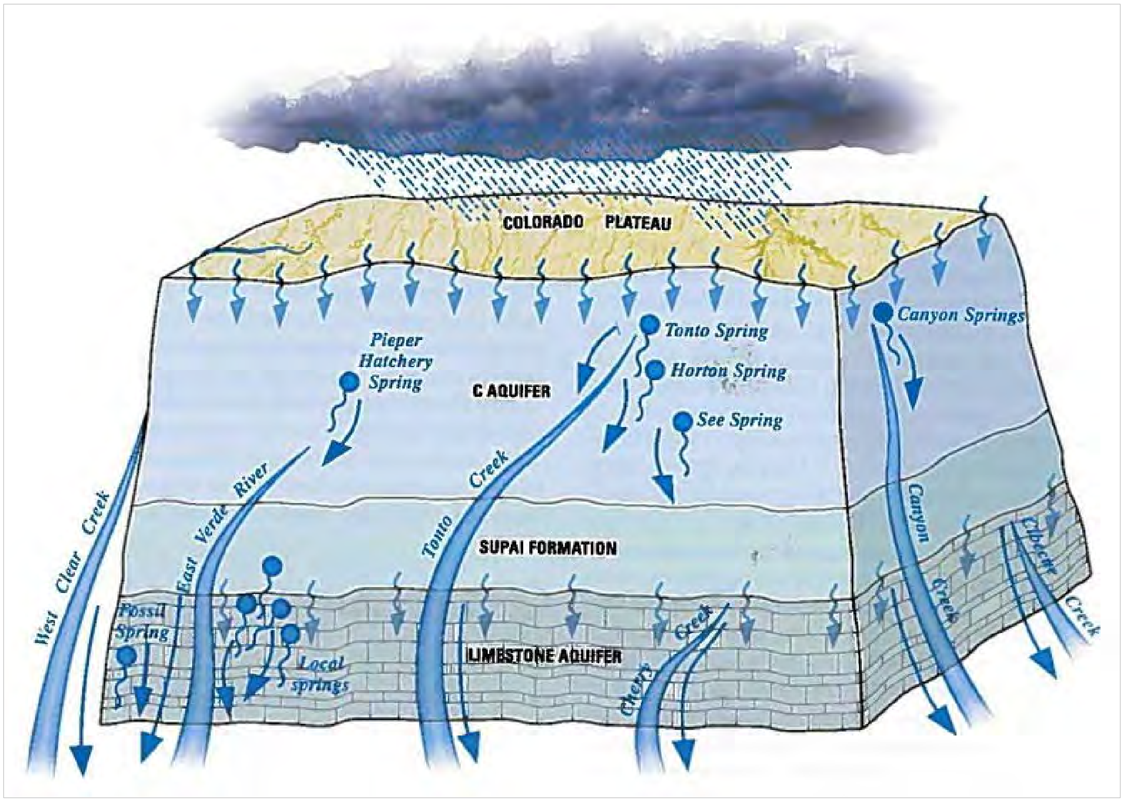


Figure 69. Groundwater recharge and discharge from the Mogollon Rim
Source: Parker et al. 2005

Thin alluvial deposits occur along many perennial, intermittent, and ephemeral streams throughout the Tonto National Forest. These aquifers can serve as valuable sources of groundwater discharge for maintaining flow in perennial streams. Thicker deposits form alluvial aquifers that are generally the most productive aquifer for cultural uses in much of the national forest.

There is relatively little groundwater development in the Verde River watershed portion of the Tonto with the exception of the Payson area. Basalt flows, conglomerates, and semiconsolidated silt units cover a large part of this subbasin. The groundwater system is complex, with disconnected recharge areas and multiple water-bearing zones. Because of its complexity, knowledge of the groundwater system is often limited to local analysis of spring and well data.

Groundwater-dependent Ecosystems

Groundwater-dependent ecosystems on the Tonto National Forest include slightly more than 1,000 springs that support valuable aquatic and riparian habitat. There are also approximately 700 miles of perennial streams on the Tonto that are supported by groundwater discharge and approximately 1,100 miles of intermittent streams where shallow groundwater elevations support obligate riparian vegetation. The Tonto National Forest also manages a portion of one fen in Little Green Valley, east of Payson. Riparian vegetation supported by groundwater discharge supports fish and wildlife habitat, filters sediment from upland runoff and flood flows, moderates stream temperatures, provides bank stability for stream channels, and helps to recharge shallow alluvial aquifers. Figure 70 displays the location of perennial and intermittent streams on the Tonto National Forest and figure 71 displays the location of springs.

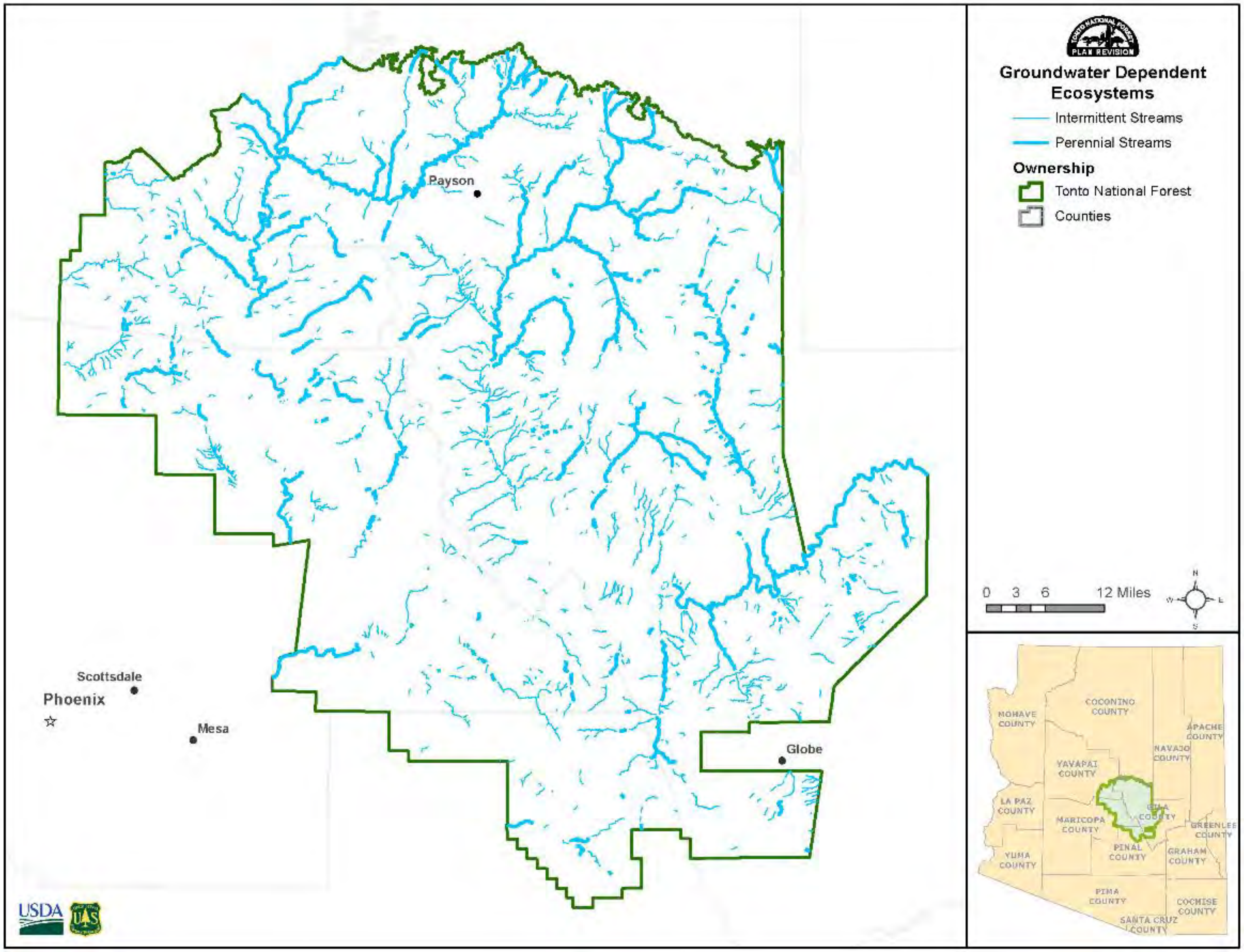


Figure 70.Groundwater-dependent ecosystems as they relate to perennial and intermittent streams

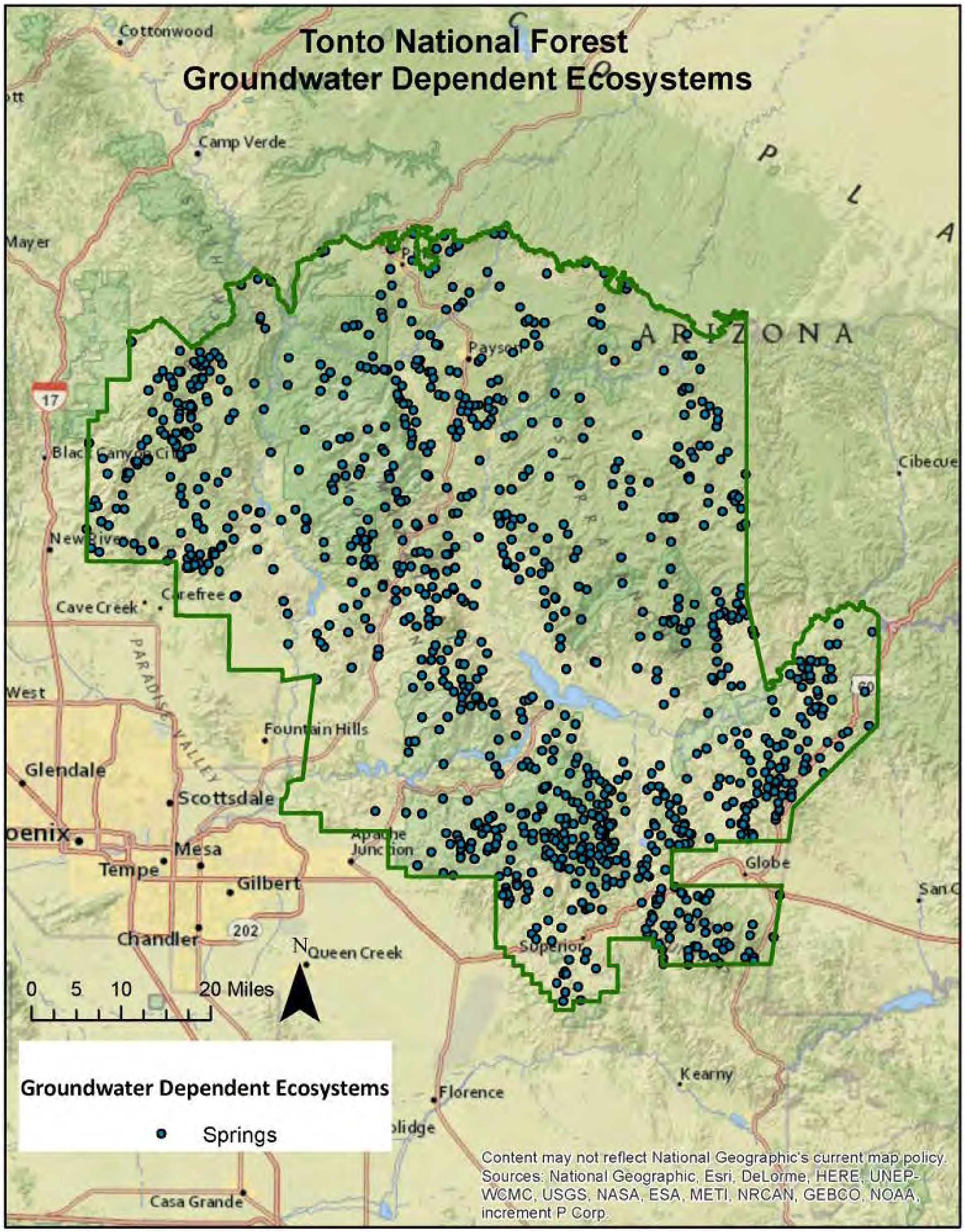


Figure 71. Locations of groundwater-dependent ecosystems as they relate to springs on the Tonto National Forest

The Verde River is supplemented by imports from C.C. Cragin Reservoir on East Clear Creek. These imports support base flow in approximately 50 miles of the East Verde River.

The remaining 510 miles of perennial streams on the Tonto National Forest are dependent on groundwater discharge to maintain perennial flow. Typically headwaters areas on these streams are areas of groundwater discharge (effluent areas). Many of these streams become losing (influent) streams as they exit mountainous areas and enter broader alluvial valleys. Many of the streams draining the Mogollon Rim area become influent streams where they cross karstic terrain. Alternating zones of gaining and losing reaches are common where canyon-bound and alluvial reaches alternate along a stream channel. Perennial streams become perennial interrupted reaches in these areas.

The U.S. Geological Survey has developed base flow indices for gaging stations across the United States. The indices estimate the portion of streamflow that is derived from base flow (base flow is defined as the component of streamflow that is attributed to groundwater discharge and other delayed sources such as snowmelt into streams (Santhi et al. 2008)). Base flow indices developed for 13 gaging stations on perennial streams on the Tonto range from 0.30 for Sycamore Creek near Sunflower to 0.76 for Pinal Creek at Inspiration Dam, and average 0.45 for the 13 gages assessed on the Tonto. The average value of 0.45 indicates almost half of the flow in many of the streams on the Tonto is derived from groundwater discharge and other sources of delayed flow. Table 107 displays base flow indices for stream gages on perennial streams within the national forest that are minimally affected by dams, diversions, and imports.

Table 107. Base flow index values for selected stream flow gages within the Tonto National Forest

USGS Gage No.	USGS Gage Name	Drainage Area (square miles)	Median Flow (cubic feet per second)	Average Base Flow Index Value
9497900	Cherry Creek near Young, AZ	62.1	1.5	0.351
9497980	Cherry Creek near Globe, AZ	200	8	0.474
9498400	Pinal Creek at Inspiration Dam, near Globe, AZ.	195	7	0.762
9498500	Salt River near Roosevelt, AZ	4,306	329	0.631
9498502	Pinto Creek near Miami, AZ	102	1.9	0.500
9498800	Tonto Creek near Gisela, AZ	430	20	0.313
9498870	Rye Creek near Gisela, AZ	122	2.7	0.319
9499000	Tonto Creek above Gun Creek, Near Roosevelt, AZ	675	22	0.316
9499500	Tonto Creek near Roosevelt, AZ	841	24	0.287
9507700	Webber Creek above West Fork Webber Creek near Pine, AZ	4.79	0.6	0.535
9507900	Webber Creek below West Fork Webber Creek near Pine, AZ	9.63	0.7	0.499
9508500	Verde River below Tangle Creek, above Horseshoe Dam, AZ	5,858	237	0.563
9510150	Sycamore Creek near Sunflower, AZ	52.3	0.5	0.302

Average Base Flow Index Value = 0.450

Source: U.S. Geological Survey (USGS) 2012

In streams with low flow volumes, base flow conditions are critical for water quality and quantity management (Santhi et al. 2008). Maintaining groundwater discharge to sustain perennial stream flow, shallow water table elevations, or both at these sites is important for the aquatic and riparian resources dependent on these features for their survival. Examples from the table above include streams such as Cherry Creek, Pinto Creek, Rye Creek, Webber Creek, and Sycamore Creek.

Groundwater Elevations

The Arizona Department of Water Resources monitors index wells across the state to collect long-term water level data (Beversdorf et al. 2009). A number of these wells lie within the boundaries of the Tonto National Forest, primarily on private lands, but a few are located on National Forest System lands. Most of the wells on private lands outside of incorporated communities are located in alluvium adjacent to stream channels. Water levels in these wells are influenced by groundwater recharged by streamflows rather than general water table trends in bedrock aquifers. A number of the index wells within the incorporated communities are within bedrock aquifers but reflect water table elevations affected by water supply pumping within these communities. Trends in water table elevations within these communities may affect groundwater-dependent ecosystems on National Forest System lands beyond the boundaries of the communities. Water level hydrographs of selected wells within the boundaries of the Tonto National Forest are displayed in the four figures below.

Figure 72 displays water level elevations in a well in the uplands of Tonto Basin near Lambing Creek (ADWR 2016). This well shows a decline in water table elevation of about 35 feet from the wet period in the late 1970s to early 1990s to the drier period in the 2000s.

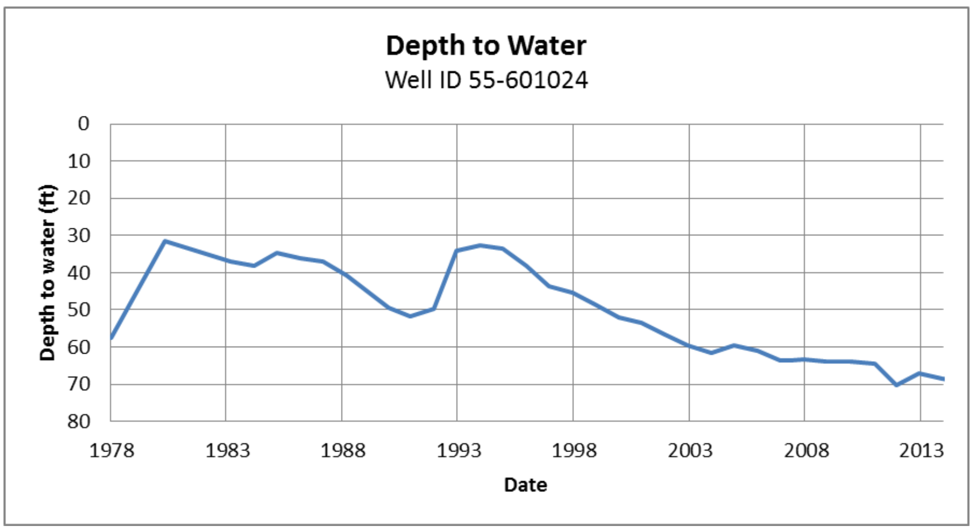


Figure 72. Depth to water, Well 55-601024, 1978 - 2015

Figure 73 displays water table elevations in a well on the Tonto National Forest close to Rye Creek adjacent to Highway 87 near Rye (ADWR 2016). Water table elevations in this well would be expected to be influenced by recharge from surface flows in Rye Creek. This chart displays a rise in water table elevations during the wet period extending from the late 1970s to the early 1990s and a decline during the dryer period of the last 15 years. There is little difference between the early 1970s and today.

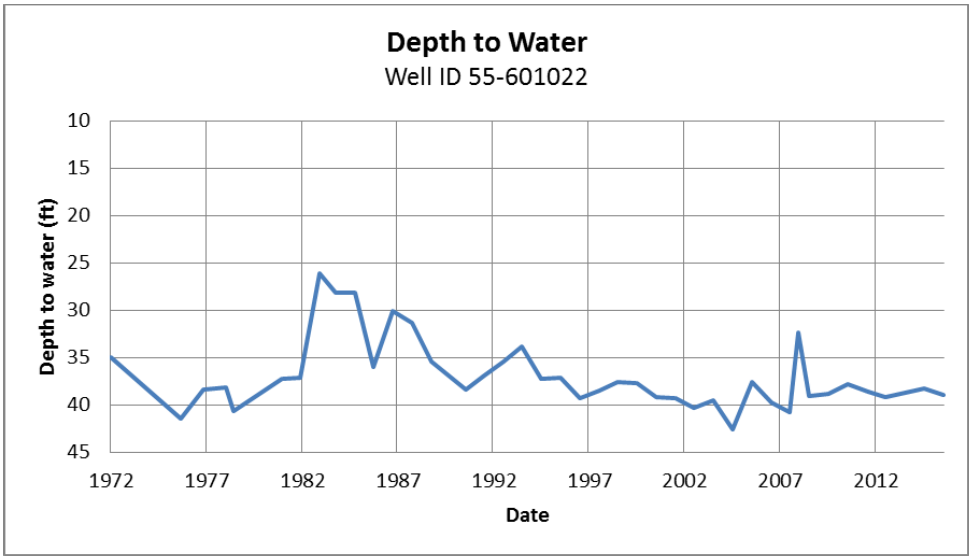


Figure 73. Depth to water, Well 55-601022, 1972 – 2015

Figure 74 shows a well located near the city of Globe water supply wellfield with a steadily declining trend in water table elevation that continues as of the end of 2014 (ADWR 2016).

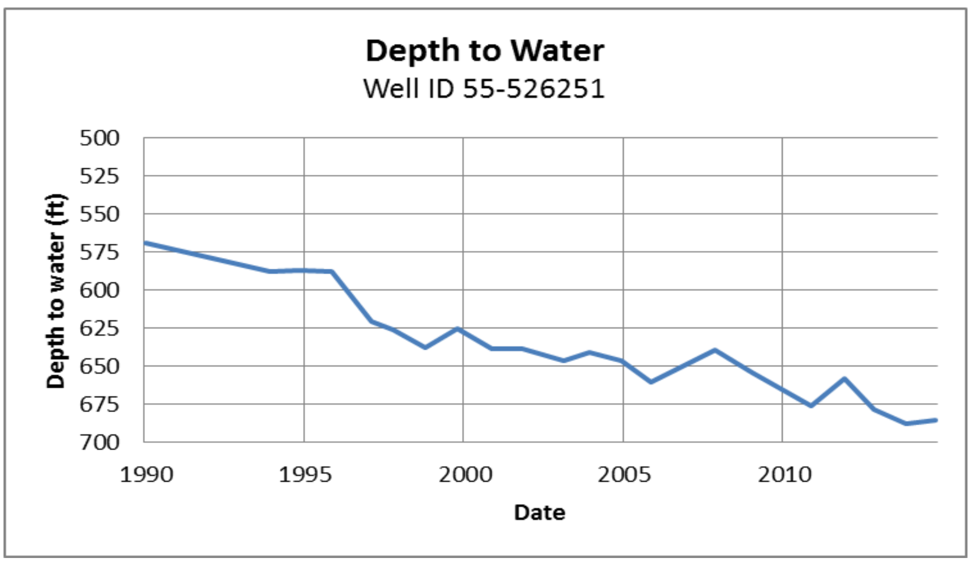


Figure 74. Depth to water, Well 55-526251 1990 – 2014

Figure 75 displays water table elevations in a well in the city of Payson (ADWR 2016). This well would be expected to be influenced by pumping from municipal supply wells in the city. The chart displays a decline in water table elevations from the late 1980s to the early 2000s and then a leveling off or even a slight rise in the water table since about 2006. An index well in the community of Strawberry displays water table elevations similar to that for Payson.

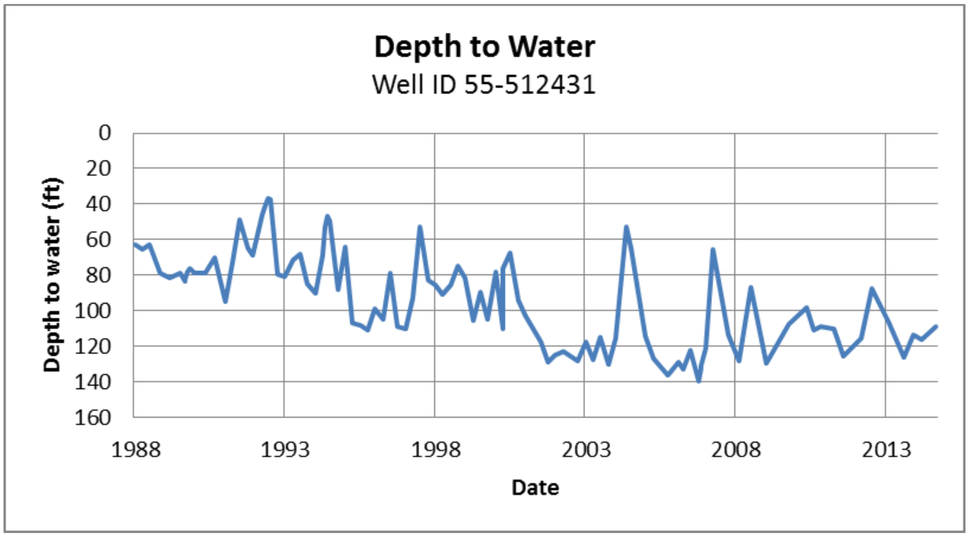


Figure 75. Depth to water, Well 55-512431, 1988 – 2015

Key Findings

Precipitation and runoff increase with elevation. The higher elevations on the Tonto National Forest compared to elevations off the national forest make the Tonto an important source of water supply for the Phoenix metropolitan area. Total runoff from the Tonto National Forest is estimated at 350,000 acre-feet per year. Precipitation and runoff have varied over time with intermittent wet and dry periods (see figure 76). Periods of drought occurred from the 1890s to about 1905, the mid 1940s to mid 1960s and from the mid-1990s to present. The period from the late 1970s through the mid 1990s is one of the wettest periods in the historical record dating back to 1895. Figure 76 displays the 5-year average standardized precipitation index for 12-month periods (Western Regional Climate Center 2015c). The 12-month standardized precipitation index is used as a drought indicator and tracks 12-month average precipitation. The 0 on the chart indicates normal precipitation, values above zero indicate above average precipitation, and values below zero indicate below average conditions.

Figure 76. Climate Division 4, 5-year average of 12-month standardized precipitation index values

The area above the Mogollon Rim escarpment is an important recharge area for the Coconino Sandstone and Redwall Limestone aquifers (Parker et al. 2005). Both aquifers are important sources of discharge to springs and perennial streams in the northern part of the Tonto National Forest along the base of the Mogollon Rim. Groundwater discharge in general is important for maintaining groundwater-dependent ecosystems (aquatic and riparian habitat) throughout the Tonto. The high base flow index values and the generally low runoff conditions in the drier parts of the Tonto mean groundwater discharge becomes even more important for maintaining aquatic and riparian habitat in these drier areas. Water table elevation charts for index wells on the Tonto do not display general downward trends in depth-to-water elevations over time.

Water Uses and Demands

The cities of Payson, Globe-Miami, and Superior lie within the exterior boundaries of the Tonto National Forest. The communities of Strawberry, Pine, Star Valley, Christopher Creek, Young, Gisela, and Tonto Basin also lie within the boundaries. Other smaller unincorporated communities also exist within the Tonto boundary. Population growth in these communities and unincorporated areas is increasing water usage. The city of Payson has been entirely dependent on groundwater for its water supply and has explored for additional water sources on the Tonto. The Arizona Water Settlement Act of 2004 allocated 3,500 acre-feet of water to communities in Northern Gila County from C.C. Cragin Reservoir (formerly Blue Ridge Reservoir). The city, which has one of the lowest per capita water use rates in the state, is constructing a pipeline to import up to 3,000 acre-feet of that water to the city. Other unincorporated communities along the pipeline route, as well as the Tonto Apache Tribe, will benefit from this water. The communities of Pine and Strawberry periodically have to ration their water supplies and actively search for new water sources. The city of Globe operates a well field on the Tonto National Forest near the border with the San Carlos Reservation. Water table elevations in an index well near the well field have declined over the years. The city is looking to reuse treated effluent to improve its water supply outlook. The city of Superior receives the majority of its water supply from wells operated by the Arizona Water Company located beyond the boundaries of the Tonto National Forest. Most water supplies for other communities are provided by wells on private lands.

Several large mines exist within the boundaries of the Tonto National Forest including Carlotta, Pinto Valley, and Miami Copper Mines in the Globe-Miami area. An additional large copper mine (Resolution Copper) is proposed within the boundaries of the Tonto and is currently undergoing environmental analysis. The existing large mines are dependent on groundwater sources for the majority of their water needs. Wells and pipelines on the Tonto National Forest provide a portion of the water needs of the Carlota and Pinto Valley mines on Pinto Creek west of Miami. Smaller mines on the Tonto that produce a variety of minerals. Water needs are typically provided by wells.

A small amount of agriculture occurs in the vicinity of Gisela. Water for agricultural use and residential watering is provided by the Gisela community ditch, which diverts surface water from Tonto Creek. Diversions for agricultural (orchards) and residential watering also occur from the East Verde River. The Tonto Basin area north of Roosevelt Lake has been growing rapidly. Most of the water to support development in the basin, as well as other developments within the boundaries of the Tonto National Forest, is derived from groundwater sources. Small surface water diversions for residential uses occur from a number of perennial streams draining the Rim country. Water for pasture irrigation and small bottled water operation is diverted from Seven Springs on the Cave Creek Ranger District

Two fish hatcheries divert water from springs on the Tonto National Forest. The Tonto Fish Hatchery diverts water from Tonto Spring in the headwaters of Tonto Creek and discharges it back to Tonto Creek after treatment. The Canyon Creek Fish Hatchery diverts water from OW Springs and discharges it to Canyon Creek.

Recreational uses of public and private lands are also a popular activity on the Tonto National Forest, particularly water-related recreation on the reservoirs and rivers. Surface water diversions from Webber Creek and Chase Creek support activities at the Camp Geronimo Boy Scout Camp and Shadow Rim Girl Scout Camp, respectively. Spring diversions provide water to recreation residence communities on Camp Creek in the Cave Creek District and Pinal Peak on the Globe District. Wells and lake intakes provide water for marinas on the reservoirs on the Salt and Verde Rivers. The Tonto National Forest is working on a water right transfer to provide water to the marinas and sheriffs aid stations on these reservoirs. The Tonto operates one well in the Phoenix active management area that has a grandfathered water right at its Goldfield administrative site.

Numerous springs and stock tanks have been developed across the Tonto to provide water for livestock and wildlife use. A small number of range wells have also been developed for livestock use.

Table 108 displays the volume of water uses within the planning area basins that are partly occupied by the Tonto National Forest. The volumes represent water use within the entire basin. The percent of each basin occupied by the Tonto is identified as well.

Table 108. Volume of water uses within planning area basins on the Tonto National Forest (NF)

Basin Name	Percent within Tonto NF	Groundwater Pumping (acre-feet per year)	Surface Water Diversions (acre-feet per year)
Agua Fria Basin	9 %	3,300	Not Reported
Verde River Basin	20 %	29,500	17,400
Tonto Creek Basin	99 %	< 3,700	1,000
Salt River Basin	50 %	< 13,100	< 11,600
Phoenix AMA	11 %	814,300	1,439,200

Source: ADWR 2009

Very little use on National Forest System lands occurs in the Agua Fria basin. However rapid development along the I-17 corridor and Prescott Valley in the context area portion of this basin is increasing the use of primarily groundwater in this basin.

The majority of the use in the Verde River basin occurs above the context area in the Middle Verde valley. Water is used for municipal and residential purposes in Payson, Pine, and Strawberry portions of the Verde basin within the Tonto National Forest. Water is stored in Horseshoe and Bartlett Lakes which are operated by the Salt River Project to provide water to water users in the Salt River Valley (Phoenix metropolitan area). The Fort McDowell Reservation diverts water below Bartlett Lake that is used for agriculture and other tribal purposes on the reservation.

Use volumes identified for the Tonto Creek Basin occur within the boundaries of the Tonto National Forest. Much of the use occurs within small communities below the Rim and in the Gisela and Tonto basin areas.

The Salt River basin includes a portion of the Apache Sitgreaves National Forest in the White Mountains and much of the Fort Apache and San Carlos Indian Reservations above the area occupied by the Tonto National Forest. Most of the water use in the portion of the near the Tonto National Forest occurs in the Globe-Miami area where copper mines are major water users. Groundwater pumping for municipal use also occurs in this area. Water is stored in reservoirs on the Salt River and is used for power generation and water supply in the Salt River Valley.

Very little of the water use within the Phoenix active management area occurs within the boundaries of the Tonto National Forest. Superior is the only community within the Tonto National Forest portion of the active management area. Groundwater pumping for residential purposes occurs on private lands within Superior and along the Queen Creek corridor. The Resolution Copper Company pumps groundwater from an existing shaft and a second shaft currently under construction to keep these shafts dewatered and pipes it for recharge and storage to an irrigation district west of the Tonto boundary.

The only use within southeastern Arizona planning area portion of the Tonto National Forest is the well field operated by Globe that is used for municipal purposes in the city.

Historical Conditions

Disturbances that affect water yield, streamflow, and groundwater are described in the general discussion of water resource disturbances in the “Watershed Extent and Perennial Streams” section. Water withdrawals through surface water diversions and groundwater pumping exceed the historical range of variation. Natural disturbances from floods and droughts are within the historical range of variation except where floods in smaller watersheds are derived from unnaturally severe wildfires.

Trends and Projections

Total water yield is directly related to precipitation. The current period of lower than normal precipitation is likely to result in a continuation of the recent trend of reduced streamflow and somewhat reduced base flows. Figure 77 and figure 78 display flow duration curves in 10-year increments since 1965 for Cherry Creek on the eastern side of the Tonto National Forest and 10-year average annual precipitation for Climate Division 4 for the same 10-year increments. The data is displayed by water year which begins in October and ends in September of the following calendar year. Base flows occur where the curves begin to flatten (ranging from approximately 30 to 40 percent exceedance) in the flow duration curve chart.

From these charts, it is evident surface runoff and base flow respond to precipitation. The top curve on the chart corresponds with runoff from water years 1976 to 1985 which is also the 10-year period with the greatest average annual precipitation (21.5 inches). The lowest curve on the chart (WY 1996 to 2005) also corresponds with the 10-year period with the least precipitation (15.8 inches).

Climate change modeling predicts that some of the most likely changes to expect in the Southwest (USDA Forest Service 2009) include:

- warmer winters with reduced snowpack,
- a delayed monsoon season,
- a five percent decline in precipitation in most of Arizona and New Mexico,
- an increase in extreme flood events, and
- temperature increases of 5 to 8 degrees Fahrenheit.

These conditions may result in reduced groundwater recharge and changes in the magnitude, frequency, and duration of stream flows. Continued growth on private lands within and beyond the boundaries of the Tonto, and the groundwater pumping associated with development on these lands, may result in reduced groundwater discharge to springs and streams on the Tonto National Forest and potentially the duration of flow in perennial streams.

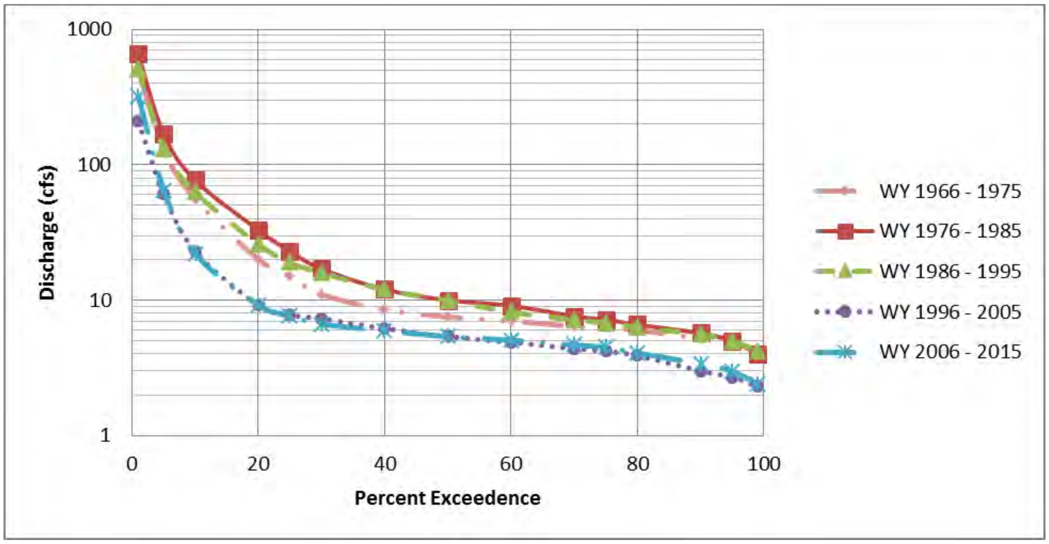


Figure 77. 10-year flow duration curves for USGS stream flow gage: Cherry Creek, near Globe, AZ (gage number 09497980)

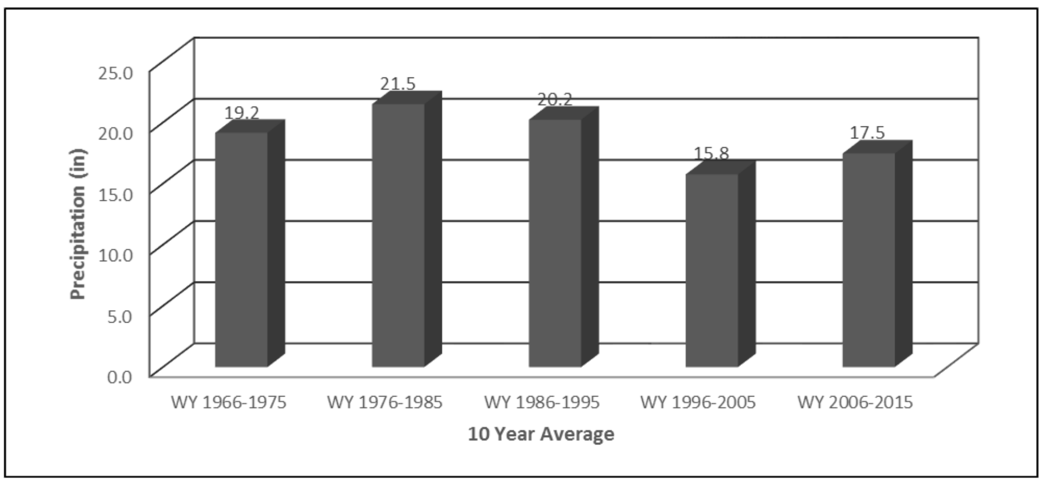


Figure 78. Ten-year average annual precipitation for Climate Division 4 (source: Western Regional Climate Center 2015a)

Risk Assessment

Risk assessments for perennial streams, springs, and seeps are based on an analysis of representativeness and redundancy described earlier. Representativeness indicates a characteristic (such as a perennial streams) is found proportionally across a subbasin or watershed. Redundancy indicates the characteristic occurs repeatedly throughout the watersheds (as in 5th-level watersheds within a 4th-level subbasin, or 6th-level subwatersheds within a 5th-level watershed. Low-risk conditions occur when the characteristic is found representative and redundant within either a subbasin or watershed. High risk conditions occur when a characteristic is neither representative nor redundant in the system of interest. Risk ratings for subbasins and watersheds are displayed in table 109 on page 311.

Water quality risk assessment ratings follow criteria provided in the Watershed Condition Classification Technical Guide (Potyondy and Geier 2011). Ratings are based on a combination of the “Impaired Waters (303(d) listed)” and the “Water Quality Problems (not listed)” attribute ratings used to assess the condition of the water quality indicator in the guide. Impaired waterbody ratings identified in the guide are as follows:

- those 6th-level subwatersheds not containing any streams rated as impaired are rated as low risk (functioning properly);
- those where streams rated as impaired occupy 0.1 to 10 percent of stream miles in the subwatershed are rated as moderate risk (functioning at risk); and
- those with streams rated as impaired that occupy greater than 10 percent of the stream miles are rated as high risk (impaired function).

The impaired waters ratings from the original assessment have been updated to reflect the most recent impaired waters ratings from the state of Arizona’s 2012/2014 Status of Water Quality Assessment 305(b) Report (ADEQ 2014). The impaired waters ratings can be modified by the water quality problems (not listed) attribute ratings also developed in the watershed condition classification assessment. These ratings are based on a number of factors including presence of abandoned mines, Arizona Department of Environmental Quality biocriteria assessments, assessment categories other than impaired from the 305(b) report, presence of fish consumption advisories, concentrated off-highway-vehicle use, and a weighted average of the watershed condition classification ratings for rangeland vegetation, channel shape and function, sediment rating from Tonto stream assessment method, and soil erosion rating.

Ratings for flow characteristics reflect the departure or potential for departure of the stream hydrograph from natural conditions. Dams, diversions, substantial groundwater pumping, effluent discharge, poor range conditions, urbanized areas, and departure from historic fire regime influenced the risk ratings. Flow characteristics risk ratings are derived primarily from the watershed condition classification ratings.

Many springs and seeps have been developed as water sources primarily for livestock use. Some have been developed for domestic use, and wildlife often benefit from the additional water sources provided by tanks and troughs. Spring and seep developments that divert water from the water source are often detrimental to the aquatic and riparian ecosystems that have developed at the sites. Risks to spring and seep resources are estimated based on the percent of these features that have been developed within a watershed. The greater the percentage of developed sources within a watershed, the greater the threat to the aquatic and riparian ecosystems supported by these features.

Groundwater-dependent ecosystems on the Tonto National Forest include springs, seeps, riparian vegetation, wetlands, and base flow in streams. These systems depend on groundwater discharge or maintenance of shallow water table conditions. Threats to these systems would occur from factors that reduce groundwater recharge (such as urban development) or intercept groundwater before it can discharge to these systems. Risks are rated primarily on the potential for upstream development to affect either groundwater recharge or discharge.

Aquatic habitat includes perennial streams, springs and seeps, and wetlands. Risk ratings include an assessment of habitat fragmentation, presence and recruitment of large woody debris, and channel shape and function. Habitat fragmentation can occur due to blockages, dewatered reaches, or changes in water temperature. Presence and recruitment of large woody debris is associated with the condition of the riparian vegetation bordering reaches of aquatic habitat. See the “Riparian Ecosystems” discussion for assessment of riparian conditions across the Tonto National Forest. Channel shape and function assess whether channel width-to-depth ratios exhibit the range of conditions expected for healthy stream channels (channels should not be widening due to bank erosion), whether channels are vertically stable (neither aggrading nor degrading above normal rates), and connected to their floodplains. The aquatic habitat ratings from the watershed condition classification assessment are provided as an indicator of risk.

Aquatic biota includes primarily an assessment of conditions in perennial streams and lakes. The assessment considers the attributes assessed in the watershed condition classification assessment. These include whether expected aquatic life forms and communities are present and basically intact based on potential natural communities present, it considers whether native aquatic communities are widespread or reduced by habitat fragmentation and pollution effects, and it considers the effects of exotic and aquatic invasive species on the condition of native species.

Roads and trails reflect the ratings in the watershed condition classification project. The ratings assess road density, proximity of roads to streams, and frequency of road maintenance. Road density less than 1 mile per square mile is considered a low threat to watershed conditions, density from 1 to 2.4 miles per square mile is considered a moderate threat, and density greater than 2.4 miles per square mile is considered a high threat. Less than 10 percent of stream miles within 300 feet of roads within a watershed is considered low threat to watershed conditions, from 10 to 25 percent is considered a moderate threat, and greater than 25 percent is considered a high threat. Best management practices applied and maintained to more than 75 percent of roads within a watershed are considered a low threat to watershed condition, application to 50 to 75 percent of road miles is considered a moderate threat, and application to less than 50 percent of roads is considered a high threat.

Soil condition ratings are also based on the watershed condition classification project. They include assessments of soil productivity, soil erosion, and soil contamination. The Southwestern Region Soil Condition Class Rating Guide (USDA Forest Service 1999) was used to assess both soil productivity and soil erosion. Soil contamination ratings were based on nutrient nitrogen ratings. Ratings for soil condition were based on the sum of unsatisfactory and impaired soils within a 6^{th}-level watershed. Rating classes are based on the following:

- 0 to 5 percent = good,
- 5 to 25 percent = fair, and
- More than 25 percent = poor.

Watershed condition ratings are the summary assessment of the watershed condition classification project for each 6^{th}-level watershed.

Table 109 presents a summary of risk for water resource characteristics and watershed condition for each subbasin, watershed, and subwatershed on the Tonto National Forest. Notes, codes, and abbreviations for the table are as follows:

Risk ratings:

- Representativeness and redundancy. Risk is based on the distribution of stream miles or springs and seeps on versus off the Tonto National Forest. Representativeness and redundancy risk ratings are applied to 4th-level subbasins and 5th-level watersheds only.
- Seeps and springs: Risk is based on the percentage of developed springs in the watershed and subwatershed zones.
  - Low = 0 to 25 percent;
  - Moderate = 25 to 50 percent
  - High = 50 percent or more;
  - NA= Insufficient for analysis or not applicable.
- Percentages listed for the subbasins and watersheds represent the percent of springs and seeps that have been developed on the Tonto. Risk is based on potential for upstream development to use groundwater that could affect groundwater dependent ecosystems in downstream subwatersheds.

Watershed condition ratings:

- FP = watershed is functioning properly
- FAR = watershed is functioning at risk
- IF= watershed has impaired function.

Table 109. Summary of risk for water resource characteristics and watershed condition

Subbasin (4th-level) Watershed (5th-level) Subwatershed (6th-level)	Watershed area on Tonto NF (%)	Perennial Stream Representativeness and Redundancy	Seeps & Springs Representativeness and Redundancy	Water Quality	Flow Characteristics	Developed Seeps and Springs	Groundwater–dependent Ecosystems	Aquatic Habitat	Aquatic Biota	Roads and trails	Soil Conditions	Watershed Conditions
San Carlos Subbasin	**9.1**	**High**	**Moderate**	**NA**	**NA**	**26%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Sevenmile Wash-Sycamore Creek	23.1	Moderate	High	NA	NA	26%	NA	NA	NA	NA	NA	NA
Corral Creek	76	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	High	High	FAR
Upper Sevenmile Wash	80	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	Moderate	High	High	FAR
Upper Sycamore Creek	19	NA	NA	Low	Low	Low	Low	Low	NA	Moderate	Moderate	FP
Champion Creek	8	NA	NA	Moderate	Moderate	Low	Low	NA	NA	High	High	FAR

Subbasin (4th-level) Watershed (5th-level) Subwatershed (6th-level)	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Gilson Wash Watershed	16.2	Moderate	Low	NA	NA	26%	NA	NA	NA	NA	NA	NA
Upper Ranch Creek	12	NA	NA	Low	Low	Moderate	Low	Moderate	NA	High	Moderate	FAR
Cutter Tank	50	NA	NA	Moderate	Moderate	Low	Moderate	Moderate	NA	High	High	FAR
Lower Ranch Creek	18	NA	NA	Moderate	Moderate	Low	Low	High	NA	High	High	FAR
Ramboz Wash	39	NA	NA	High	Moderate	Moderate	Low	Moderate	NA	High	High	FAR
Middle Gila Subbasin	**7.8**	**High**	**High**	**NA**	**NA**	**42%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Dripping Springs Wash-Gila River	1.3	High	Moderate	NA	NA	43%	NA	NA	NA	NA	NA	NA
Silver Creek	16	NA	NA	Moderate	Low	Moderate	Low	High	NA	High	Moderate	FAR
Mineral Creek-Gila River	21.3	High	Moderate	NA	NA	48%	NA	NA	NA	NA	NA	NA
Lyons Fork	84	NA	NA	High	Low	Moderate	Low	Moderate	High	High	Moderate	FAR
Devils Canyon	60	NA	NA	Moderate	Low	Low	High	High	NA	High	Moderate	FAR
Upper Mineral Creek	49	NA	NA	High	Moderate	High	Low	High	High	High	High	IF
Box O Wash-Gila River	1.5	High	Low	NA	NA	50%	NA	NA	NA	NA	NA	NA
Walnut Canyon	14	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	Moderate	High	FAR
Box Canyon-Gila River	5	NA	NA	Moderate	Moderate	NA	Low	NA	NA	Moderate	High	FAR
Upper Queen Creek	99.4	Moderate	Moderate	NA	NA	43%	NA	NA	NA	NA	NA	NA
Arnett Creek	99	NA	NA	High	High	Low	High	Moderate	High	High	High	FAR
Silver King Wash-Queen Creek	100	NA	NA	High	High	High	High	Low	High	High	High	IF
Potts Canyon	100	NA	NA	High	High	Moderate	High	Moderate	NA	High	High	FAR
Hewitt Canyon	100	NA	NA	High	Moderate	Moderate	Low	High	NA	High	High	IF
Alamo Canyon-Queen Creek	99	NA	NA	High	Moderate	Moderate	High	High	NA	High	High	IF
Paisano Wash-Gila River	0.4	High	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cottonwood Canyon	5	NA	NA	Moderate	NA	NA	Low	NA	NA	High	High	FAR
Middle Queen Creek	12.9	Moderate	High	NA	NA	10%	NA	NA	NA	NA	NA	NA
Whitlow Canyon	57	NA	NA	High	Low	Low	Low	High	NA	Moderate	Moderate	FAR
Weekes Wash	63	NA	NA	Moderate	Moderate	High	Low	NA	NA	High	High	IF

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Siphon Draw	23	NA	NA	Low	Low	Low	Low	Moderate	NA	Low	High	FAR
Peralta Canyon	9	NA	NA	Low	Low	Low	Low	Low	NA	Low	High	FP
Apache Land Tank	9	NA	NA	Low	Low	NA	Low	NA	NA	Low	High	FP
Lower Queen Creek	1.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upper Salt Subbasin	**55.6**	**Low**	**Moderate**	**NA**	**NA**	**30%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Sawmill Creek-Salt River	6.2	High	Moderate	NA	NA	67%	NA	NA	NA	NA	NA	NA
Tanks Canyon	14	NA	NA	Moderate	Low	NA	Low	NA	NA	High	Moderate	FAR
Cienega Creek-Salt River	30	NA	NA	High	Moderate	High	Low	Moderate	High	High	High	IF
Canyon Creek	20.6	Moderate	High	NA	NA	62%	NA	NA	NA	NA	NA	NA
Canyon Creek Headwaters		NA	NA	Low	Moderate	Low	Moderate	Moderate	High	High	Low	FAR
Upper Canyon Creek	10	NA	NA	Low	Low	NA	Low	NA	NA	High	Low	FAR
Gentry Canyon	78	NA	NA	Low	Low	Low	Moderate	Moderate	Low	High	Moderate	FAR
Ellison Creek	53	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	FAR
Sloan Creek	48	NA	NA	Low	Low	High	Low	Moderate	Moderate	High	High	FAR
Rock House Canyon	52	NA	NA	Low	Low	High	Low	Low	NA	High	High	FAR
Willow Creek	35	NA	NA	Low	Low	NA	Low	NA	NA	High	Moderate	FAR
Cherry Creek	95.3	Moderate	Moderate	NA	NA	44%	NA	NA	NA	NA	NA	NA
Parallel Canyon-Cherry Creek	94	NA	NA	Low	Low	Low	Low	Moderate	High	High	Low	FAR
Pleasant Valley	100	NA	NA	Moderate	Moderate	NA	High	Moderate	Moderate	High	High	IF
Crouch Creek	100	NA	NA	Moderate	Low	High	Moderate	Moderate	Moderate	Moderate	High	FAR
Gruwell Canyon-Cherry Creek	100	NA	NA	Low	Moderate	Moderate	High	Moderate	Moderate	High	Moderate	FAR
Wilson Creek	100	NA	NA	Moderate	Low	High	Low	Moderate	NA	High	High	FAR
Walnut Creek-Cherry Creek	100	NA	NA	Low	Low	Low	High	High	Moderate	High	Moderate	FAR
P B Creek-Cherry Creek	100	NA	NA	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	FAR
Cooper Forks-Cherry Creek	100	NA	NA	Moderate	Moderate	High	Moderate	High	Moderate	Moderate	Moderate	FAR
Bladder Canyon-Cherry Creek	79	NA	NA	Moderate	High	Low	Moderate	High	Moderate	Moderate	High	FAR
Salt River Draw-Salt River	55.8	Low	Moderate	NA	NA	37%	NA	NA	NA	NA	NA	NA

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Rock Canyon-Salt River	49	NA	NA	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate	High	FAR
Ash Creek	100	NA	NA	High	Moderate	Low	Moderate	High	Moderate	High	High	FAR
Hess Canyon	100	NA	NA	High	Moderate	Moderate	Low	High	NA	High	High	IF
Butte Creek-Salt River	60	NA	NA	High	Moderate	Moderate	Low	Moderate	Moderate	Moderate	High	FAR
Yankee Joe Canyon- Salt River	90	NA	NA	High	Moderate	Moderate	Low	Moderate	Moderate	Moderate	High	FAR
Pinal Creek	77.5	Moderate	Low	NA	NA	47%	NA	NA	NA	NA	NA	NA
Russell Gulch	73	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	High	High	FAR
Bloody Tanks Wash	55	NA	NA	Moderate	Low	Moderate	Low	High	NA	High	Low	FAR
Miami Wash	42	NA	NA	Moderate	Moderate	High	Low	High	NA	High	Moderate	IF
Upper Pinal Creek	61	NA	NA	High	Moderate	Low	Low	High	NA	High	High	IF
Horseshoe Bend Wash	100	NA	NA	Moderate	Moderate	High	Low	High	NA	High	High	IF
Middle Pinal Creek	100	NA	NA	High	Moderate	High	Moderate	High	High	High	High	IF
Lower Pinal Creek	100	NA	NA	Moderate	High	Moderate	High	High	High	Moderate	High	IF
Pinto Creek	100	Low	Low	NA	NA	18%	NA	NA	NA	NA	NA	NA
Haunted Canyon	100	NA	NA	Moderate	High	Low	High	Moderate	High	High	Moderate	FAR
West Fork Pinto Creek	100	NA	NA	Moderate	Low	Low	Low	Moderate	Low	Moderate	Moderate	FAR
Upper Pinto Creek	100	NA	NA	High	High	Low	High	Moderate	High	High	Moderate	FAR
Middle Pinto Creek	100	NA	NA	High	Moderate	Low	High	Moderate	High	Moderate	High	FAR
Campaign Creek	100	NA	NA	Moderate	Moderate	High	Low	Moderate	High	Moderate	High	FAR
Lower Pinto Creek	100	NA	NA	High	Moderate	High	High	Low	High	High	High	FAR
Salome Creek	100	Low	Low	NA	NA	43%	NA	NA	NA	NA	NA	NA
Reynolds Creek	100	NA	NA	Low	Low	Low	Low	Moderate	High	High	Moderate	FAR
Workman Creek	100	NA	NA	Low	Low	Moderate	Moderate	Moderate	High	High	Moderate	FAR
Upper Salome Creek	100	NA	NA	Low	Low	High	Low	Low	Moderate	High	Moderate	FAR
Middle Salome Creek	100	NA	NA	Low	Low	Moderate	Low	Low	Moderate	Moderate	Moderate	FP
Lower Salome Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Low	Moderate	High	High	FAR

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Salt River-Theodore Roosevelt Lake	100	Moderate	Moderate	NA	NA	42%	NA	NA	NA	NA	NA	NA
Coon Creek	100	NA	NA	Low	Low	Low	Moderate	High	Low	Moderate	High	FAR
Chalk Creek	100	NA	NA	Moderate	Moderate	Low	Low	Moderate	NA	High	High	FAR
Sycamore Canyon-Salt River	100	NA	NA	High	Moderate	High	Low	Moderate	Moderate	Moderate	High	FAR
Shute Springs Creek- Salt River	100	NA	NA	Moderate	Moderate	High	Low	Moderate	Moderate	Moderate	High	FAR
Meddler Wash-Salt River	100	NA	NA	High	Moderate	High	Low	Moderate	Moderate	High	High	FAR
Griffin Wash	100	NA	NA	Moderate	Moderate	High	Low	Moderate	NA	High	High	FAR
Cottonwood Wash	100	NA	NA	Moderate	Moderate	Low	Low	High	NA	High	High	FAR
Armer Gulch	100	NA	NA	Moderate	Moderate	Low	Low	Moderate	NA	Moderate	High	FAR
Schell Gulch-Salt River	100	NA	NA	High	High	Moderate	Low	Moderate	Moderate	High	High	IF
Cottonwood Creek-Salt River	100	NA	NA	High	High	High	Low	Moderate	Moderate	Moderate	High	IF
Tonto Subbasin	**99**	**Low**	**Low**	**NA**	**NA**	**40%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Spring Creek	100	Low	Moderate	NA	NA	47%	NA	NA	NA	NA	NA	NA
Buzzard Roost Canyon	100	NA	NA	Low	Low	Low	Low	Moderate	Moderate	High	Low	FAR
Rock Creek	100	NA	NA	Moderate	Low	High	Low	Moderate	Moderate	High	Moderate	FAR
Upper Spring Creek	100	NA	NA	Low	Low	Moderate	Low	Moderate	Moderate	High	Moderate	FAR
Walnut Creek	100	NA	NA	Low	Low	NA	Moderate	Moderate	High	High	High	FAR
Middle Spring Creek	100	NA	NA	Low	Low	High	Low	Moderate	Moderate	High	High	FAR
Lower Spring Creek	100	NA	NA	Low	Low	High	Low	Moderate	Moderate	Moderate	Moderate	FP
Haigler Creek-Tonto Creek	95.5	Low	Low	NA	NA	18%	NA	NA	NA	NA	NA	NA
Marsh Creek	100	NA	NA	Low	Low	Moderate	Low	Moderate	Moderate	High	High	FAR
Gordon Canyon	100	NA	NA	Low	Low	Moderate	Moderate	Moderate	Moderate	High	Moderate	FAR
Christopher Creek	100	NA	NA	High	Moderate	Low	Moderate	Moderate	High	High	Low	IF
Horton Creek-Tonto Creek	100	NA	NA	High	Moderate	Low	Moderate	Moderate	High	High	Moderate	FAR
Haigler Creek	100	NA	NA	Low	Low	Low	Moderate	Moderate	Moderate	High	Moderate	FAR
Bull Tank Canyon-Tonto Creek	100	NA	NA	High	Moderate	Low	Moderate	High	Moderate	Moderate	Moderate	FAR

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Big Canyon-Tonto Creek	100	NA	NA	High	Low	NA	Low	Moderate	Moderate	Moderate	Moderate	FP
Rye Creek-Tonto Creek	100	Moderate	Low	NA	NA	44%	NA	NA	NA	NA	NA	NA
Green Valley Creek	100	NA	NA	Moderate	Moderate	High	Moderate	Moderate	Low	High	High	FAR
Soldier Camp Creek	100	NA	NA	Low	Low	Low	Low	Moderate	Low	High	Moderate	FP
Gibson Creek	100	NA	NA	Moderate	Moderate	High	Moderate	Moderate	NA	High	High	FAR
Houston Creek	100	NA	NA	High	Moderate	Low	High	Moderate	High	High	High	IF
Dry Pocket Wash-Tonto Creek	100	NA	NA	High	Low	Low	Low	Moderate	High	Moderate	Moderate	FAR
Saint Johns Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Low	NA	High	High	FAR
Upper Rye Creek	100	NA	NA	Moderate	Moderate	High	Low	Moderate	NA	High	High	FAR
Deer Creek	100	NA	NA	Low	Low	High	Low	Moderate	Moderate	Moderate	Moderate	FP
Lower Rye Creek	100	NA	NA	Moderate	Moderate	High	High	Moderate	High	High	High	FAR
Cocomunga Canyon-Tonto Creek	100	NA	NA	High	High	Moderate	Moderate	Moderate	High	High	High	IF
Hardt Creek-Tonto Creek	100	NA	NA	High	Moderate	Low	Moderate	Moderate	High	High	High	IF
Gun Creek-Tonto Creek	100	Moderate	Low	NA	NA	48%	NA	NA	NA	NA	NA	NA
Gun Creek	100	NA	NA	Low	Low	High	Low	Moderate	Moderate	Moderate	Moderate	FP
Slate Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	IF
Packard Wash-Tonto Creek	100	NA	NA	High	Moderate	Moderate	Moderate	Moderate	High	High	High	FAR
Cottonwood Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	High	High	FAR
Oak Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	High	High	FAR
Lambing Creek-Tonto Creek	100	NA	NA	High	Moderate	High	High	High	High	High	High	IF
Sycamore Creek	100	NA	NA	Moderate	Low	Moderate	Low	Moderate	High	Moderate	High	FAR
Greenback Creek	100	NA	NA	Moderate	Moderate	Moderate	High	Moderate	High	High	High	FAR
Ash Creek-Tonto Creek	100	NA	NA	High	Moderate	Moderate	High	Moderate	High	High	High	FAR
Tonto Creek- Theodore Roosevelt Lake	100	Moderate	Low	NA	NA	20%	NA	NA	NA	NA	NA	NA
Rock Creek	100	NA	NA	Low	Low	Low	Low	Low	High	Moderate	Moderate	FP
Methodist Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Low	NA	Moderate	High	FAR

Subbasin (4th-level) Watershed (5th-level) Subwatershed (6th-level)	Watershed area on Tonto NF (%)	Perennial Stream Representativeness and Redundancy	Seeps & Springs Representativeness and Redundancy	Water Quality	Flow Characteristics	Developed Seeps and Springs	Groundwater–dependent Ecosystems	Aquatic Habitat	Aquatic Biota	Roads and trails	Soil Conditions	Watershed Conditions
Bumblebee Creek-Tonto Creek	100	NA	NA	High	High	High	High	Moderate	High	High	High	FAR
Mills Canyon-Tonto Creek	100	NA	NA	High	High	Low	Low	Moderate	High	High	High	IF
Lower Salt Subbasin	**45.9**	**High**	**High**	**NA**	**NA**	**19%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Salt River-Apache, Canyon, and Saguaro Lake	100	Moderate	Moderate	NA	NA	19%	NA	NA	NA	NA	NA	NA
Pine Creek	100	NA	NA	Low	Low	Low	Low	Low	High	Low	High	FP
Buckhorn Creek-Salt River	100	NA	NA	High	High	Low	Low	Moderate	High	Moderate	High	FAR
Salt River-Apache Lake	100	NA	NA	High	High	Moderate	Low	Moderate	High	Low	High	IF
Lewis and Pranty Creek	100	NA	NA	Low	Low	Low	Low	Moderate	Moderate	Low	High	FAR
Fish Creek	100	NA	NA	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate	FP
Tortilla Creek	100	NA	NA	Moderate	Moderate	Low	Low	Low	Moderate	Low	High	FP
La Barge Creek	100	NA	NA	Moderate	Low	Low	Low	Low	NA	Low	High	FP
Salt River-Canyon Lake	100	NA	NA	High	High	Low	Low	Moderate	High	Low	High	FAR
Cane Spring Canyon	100	NA	NA	Moderate	Moderate	High	Low	Moderate	NA	Moderate	High	FAR
Cottonwood Creek	100	NA	NA	Moderate	Moderate	High	Low	High	NA	Moderate	High	IF
Willow Springs Canyon	100	NA	NA	Moderate	Moderate	Low	Low	Low	NA	Moderate	High	FAR
Jones Canyon	100	NA	NA	High	Moderate	NA	Low	NA	NA	High	High	IF
Salt River-Saguaro Lake	100	NA	NA	Moderate	High	NA	Low	Moderate	High	High	High	IF
Indian Bend Wash	0.4	NA	High	NA	NA	NA	NA	NA	NA	NA	NA	NA
Salt River below Saguaro Lake	15.7	High	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bulldog Wash-Buckhorn Mesa FRS	19	NA	NA	Moderate	Moderate	NA	Low	NA	NA	Moderate	High	FAR
Bulldog Canyon-Salt River	94	NA	NA	Moderate	High	NA	Moderate	Moderate	High	Moderate	High	IF
Lower Verde Subbasin	**66**	**Low**	**Low**	**NA**	**NA**	**55%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
East Verde River	95.8	Moderate	Low	NA	NA	28%	NA	NA	NA	NA	NA	NA
Ellison Creek	100	NA	NA	Moderate	Moderate	Low	Moderate	Low	Moderate	High	Moderate	FAR
East Verde River Headwaters	100	NA	NA	Low	High	Low	Moderate	High	Moderate	High	Moderate	FAR
Webber Creek	100	NA	NA	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	Moderate	FAR

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
American Gulch	99	NA	NA	Moderate	Low	High	High	Moderate	NA	High	High	FAR
Upper East Verde River	100	NA	NA	High	Moderate	Low	Moderate	Moderate	Moderate	High	High	FAR
Pine Creek	100	NA	NA	Low	High	Low	Moderate	High	Moderate	Moderate	Moderate	FAR
Middle East Verde River	100	NA	NA	High	Moderate	High	High	Moderate	Moderate	High	High	FAR
Rock Creek	100	NA	NA	Moderate	Moderate	Low	Low	Moderate	NA	Moderate	High	FAR
The Gorge	100	NA	NA	Moderate	Moderate	Low	Low	Moderate	NA	Moderate	High	FAR
Lower East Verde River	100	NA	NA	High	Moderate	High	Moderate	Moderate	Moderate	Low	High	FAR
Fossil Creek-Verde River	20.8	Low	Moderate	NA	NA	67%	NA	NA	NA	NA	NA	NA
Hardscrabble Creek	100	NA	NA	Moderate	Moderate	Low	High	Moderate	NA	Moderate	High	FAR
Lower Fossil Creek		NA	NA	Low	Low	Low	Low	Low	Moderate	Low	High	NA
Gap Creek-Verde River		NA	NA	Moderate	Moderate	High	Moderate	Low	High	Moderate	High	NA
Tangle Creek-Verde River	100	Moderate	Moderate	NA	NA	66%	NA	NA	NA	NA	NA	NA
Houston Creek	100	NA	NA	Moderate	Moderate	High	Low	High	Moderate	Moderate	Moderate	FAR
Middle Red Creek	100	NA	NA	Moderate	Low	High	Low	Moderate	Moderate	Moderate	Moderate	FAR
Red Creek	100	NA	NA	Moderate	Moderate	High	Low	High	Moderate	High	High	FAR
Canyon Creek-Verde River	100	NA	NA	Moderate	Moderate	High	Moderate	Moderate	High	Low	High	FAR
Wet Bottom Creek	100	NA	NA	Moderate	Moderate	High	Low	Moderate	Low	Low	High	FAR
Tangle Creek	100	NA	NA	High	Moderate	High	Low	High	Moderate	Moderate	High	FAR
Sycamore Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Low	Moderate	Low	High	FP
Horse Creek	100	NA	NA	Moderate	Moderate	High	Low	Moderate	Moderate	Moderate	High	FAR
Dry Wash-Verde River	10	NA	NA	Low	Moderate	Moderate	Moderate	Moderate	High	Low	High	FAR
Verde River-Horseshoe and Bartlett Reservoir	100	Low	Moderate	NA	NA	61%	NA	NA	NA	NA	NA	NA
Deadman Creek	100	NA	NA	Low	Low	High	Low	Moderate	Moderate	Moderate	Moderate	FP
Lime Creek	100	NA	NA	Moderate	Moderate	High	Low	Moderate	Moderate	Moderate	High	FAR
Lower Verde River-Horseshoe Res.	100	NA	NA	Moderate	High	NA	Moderate	High	Moderate	Moderate	High	FAR
Davenport Wash	100	NA	NA	Moderate	Moderate	High	Low	High	Moderate	Moderate	High	FAR

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
South Fork Sheep Creek	100	NA	NA	Low	Low	Moderate	Low	High	Moderate	Low	Moderate	FP
Sheep Creek	100	NA	NA	Low	Low	High	Low	High	Moderate	Low	Moderate	FP
Buck Basin-Verde River	100	NA	NA	Moderate	High	Moderate	Moderate	High	Moderate	High	High	IF
Alder Creek	100	NA	NA	Low	Moderate	Moderate	Low	Low	Low	Moderate	High	FP
Lower Verde River-Bartlett Res.	100	NA	NA	High	High	Moderate	Low	High	High	Moderate	High	IF
Sycamore Creek	98.7	Moderate	Low	NA	NA	63%	NA	NA	NA	NA	NA	NA
Upper Sycamore Creek	100	NA	NA	Moderate	Low	High	Moderate	Moderate	High	High	High	FAR
Rock Creek	100	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	Moderate	High	FAR
Mesquite Wash	100	NA	NA	Moderate	Moderate	High	Low	Moderate	High	High	High	FAR
Middle Sycamore Creek	100	NA	NA	Moderate	Moderate	High	Moderate	Moderate	High	High	High	FAR
Lower Sycamore Creek	94	NA	NA	Moderate	Moderate	High	Moderate	Moderate	High	High	High	IF
Camp Creek-Verde River	56.3	Moderate	Moderate	NA	NA	21%	NA	NA	NA	NA	NA	NA
Camp Creek	99	NA	NA	High	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	IF
Indian Spring Wash-Verde River	100	NA	NA	High	High	Low	Low	Moderate	High	High	High	IF
Cottonwood Basin-Verde River	87	NA	NA	Moderate	High	Low	Low	Moderate	High	High	High	FAR
Malpais Canyon-Verde River	75	NA	NA	Moderate	High	Low	Low	Moderate	High	High	High	IF
Lousely Hill-Verde River	12	NA	NA	Moderate	NA	NA	Low	NA	NA	Moderate	High	FAR
Agua Fria Subbasin	**10.4**	**High**	**Moderate**	**NA**	**NA**	**55%**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Sycamore Creek-Agua Fria River	28.6	High	Mod	NA	NA	39%	NA	NA	NA	NA	NA	NA
Silver Creek	69	NA	NA	High	Low	High	Low	High	Low	Moderate	High	FAR
Bishop Creek	80	NA	NA	High	Low	High	Low	High	NA	High	High	IF
Tank Creek	42	NA	NA	Moderate	Moderate	High	Low	NA	NA	High	High	FAR
Squaw Creek	94	NA	NA	Moderate	Moderate	Moderate	Low	High	NA	Moderate	High	FAR
Lousy Canyon-Agua Fria River	13	NA	NA	Moderate	Moderate	High	Low	NA	NA	Moderate	High	FAR
Agua Fria River-Lake Pleasant	3.1	High	High	NA	NA	25%	NA	NA	NA	NA	NA	NA
Little Squaw Creek	39	NA	NA	Moderate	Moderate	Low	Low	Moderate	NA	Moderate	High	FAR

Subbasin (4th-level) **Watershed (5th-level)** **Subwatershed (6th-level)**	**Watershed area on Tonto NF (%)**	**Perennial Stream Representativeness and Redundancy**	**Seeps & Springs Representativeness and Redundancy**	**Water Quality**	**Flow Characteristics**	**Developed Seeps and Springs**	**Groundwater–dependent Ecosystems**	**Aquatic Habitat**	**Aquatic Biota**	**Roads and trails**	**Soil Conditions**	**Watershed Conditions**
Moore Gulch	26	NA	NA	Moderate	Moderate	Moderate	Low	Moderate	NA	Moderate	High	FAR
Cave Creek-Arizona Canal Diversion Channel	31.1	Moderate	Moderate	NA	NA	72%	NA	NA	NA	NA	NA	NA
Seven Springs Wash-Cave Creek	100	NA	NA	Moderate	Moderate	High	Moderate	Moderate	Moderate	High	High	FAR
Galloway Wash-Cave Creek	54	NA	NA	Moderate	Moderate	High	Moderate	Moderate	Moderate	Low	High	FAR
New River	22.5	Moderate	High	NA	NA	63%	NA	NA	NA	NA	NA	NA
Grapevine Canyon-New River	100	NA	NA	Moderate	Moderate	High	Low	High	High	Moderate	High	IF
Cline Creek	62	NA	NA	Moderate	Moderate	Moderate	Low	High	NA	Moderate	High	IF
Upper Skunk Creek	38	NA	NA	Moderate	Moderate	Moderate	Low	High	NA	High	High	IF

Perennial Streams

The risk rating for perennial streams in the San Carlos, Middle Gila, and Agua Fria subbasins is high due to under representation and low redundancy on the Tonto National Forest portion of the subbasins. There are no perennial streams on the Tonto National Forest portion of the San Carlos subbasin, only 2 miles of perennial streams in the Tonto portion of the Middle Gila subbasin, and 3 miles in the Agua Fria subbasin. The risk rating is low on the Upper Salt, Tonto, and Lower Verde subbasins due to similar conditions in the portion outside Tonto in these subbasins (99 percent of the Tonto subbasin lies within the Tonto National Forest) as on the Tonto portions. Perennial streams on the Tonto are representative and redundant of conditions outside the Tonto. The risk rating for perennial streams in the Lower Salt subbasin is high due to the high percentage of perennial streams on the Tonto. Diversions at Granite Reef Dam reduce the miles of perennial streams beyond the Tonto's boundary. Perennial streams are only found in one watershed within this subbasin which results in low redundancy. There is no real trend in the presence or absence of perennial streams, although increased groundwater pumping within the exterior boundaries of the Tonto National Forest may reduce the miles of perennial streams over time.

Water Quality

Water quality impairment on the Tonto National Forest can be found primarily in areas with historic mining such as the Pinto Creek and Queen Creek watersheds and in areas with heavy recreation use and summer homes such as the headwaters of Tonto Creek and Christopher Creek. A recent development has been to designate a number of waterbodies as impaired due to mercury contamination in fish. Affected waterbodies include much of the mainstem of Tonto Creek and Roosevelt Lake. Arizona Department of Environmental Quality is investigating the source of these impairments but has not reached any conclusions yet. Other sources of impairment include low dissolved oxygen in reservoirs on the Salt River. Other waterbodies are impaired for reasons that don't fall into general categories of impairment such as those mentioned above.

Although there have been several Arizona Department of Environmental Quality water quality assessments in the last two decades, it is difficult to quantitatively identify trends. This is due to evolving and changing sampling and testing protocols, standards, and documentation. In addition, some standards have changed and the legislated requirement for credible data places a more stringent requirement on rigorous scientific data collection and analysis.

A greater number of miles of streams were identified as impaired in the 2012/2014 303(d) list (list of impaired waterbodies) than in the 2010 303(d) list. Much of the increase is attributed to addition of 62 miles of Tonto Creek due to discovery of high levels of mercury in fish tissue. Part of the increase may also be due to a greater number of stream miles assessed on the Tonto National Forest in the 2012/2014 assessment (663 miles) than in the 2010 assessment (513 miles). The percent of stream miles assessed as impaired on the Tonto increased from 21 percent in 2010 to 25 percent in 2012/2014.

Streams and waterbodies identified as impaired in Arizona Department of Environmental Quality's biannual 305(b)assessment and 303(d) listing reports had, or will have, total maximum daily loads prepared that recommend actions to bring water quality into compliance with surface water standards. Water quality in the streams identified in the water quality assessment section should improve as activities recommended in total maximum daily load analyses are implemented.

Flow Characteristics

Flow characteristics are rated based on the findings in the watershed condition classification project and include factors such as dams and diversions, mine retention structures, groundwater pumping, effluent discharge, water imports, watersheds rated with poor range condition, recent fires, and urbanized areas. Only watersheds with perennial streams were rated.

Watersheds including parts of Roosevelt Lake and along the lower Salt and Verde Rivers were rated high risk due to reservoirs and controlled releases. Watersheds along the East Verde were rated high risk due to imports from C.C. Cragin Reservoir. Areas with concentrations of large mines were rated high risk due to retention structures, diversions, and groundwater pumping. Watersheds below urbanized areas such as Globe-Miami, Payson, and Pine were rated high risk as well. There is an increasing trend towards development on private lands, particularly in Tonto Basin and below the Mogollon Rim. Potential for increased development also exists in the Young area. Development increases hardened surfaces and the flashiness of runoff. It also will likely result in increased groundwater pumping. Little change in reservoir operations is anticipated. The effects of mines will likely increase development of the Resolution Copper Mine.

Seeps and Springs

Risk ratings were high for the Middle Gila and Lower Salt subbasins due to over representativeness and low redundancy. Ratings were moderate in the San Carlos, Upper Salt, and Agua Fria subbasins due to over representativeness and moderate redundancy. Risk ratings were low in the Tonto and Lower Verde subbasins due to proportional representativeness and moderate redundancy.

Trends for springs and seeps are somewhat comparable to those for perennial streams. Trends are variable depending on local conditions. Resources supported by springs and seeps are generally resilient as long as water continues to discharge from the source. Springs and seeps are attractive for livestock, wildlife, and human use and require management to prevent excessive use which can lead to degradation. Climate change may result in drier conditions and more erratic rainfall patterns that may reduce aquifer recharge and consequently discharge from springs and seeps.

Developed Seeps and Springs

Risks ratings were developed for watersheds and subwatersheds. Subbasins with a higher numbers of high risk watersheds include the Lower Verde and Agua Fria subbasins. Three of six watersheds in the Lower Verde and three of four watersheds in the Aqua Fria are rated as high risk. The Lower Salt subbasin is the only subbasin to have only low risk ratings for the watersheds in the subbasin. The San Carlos subbasin is the only subbasin to have only moderate risk ratings for the watersheds in the subbasin. Overall 9 watersheds were rated as high risk, 18 as moderate risk, and 4 as low risk.

Developed springs and seeps often reduce the value of the resources supported by these features because water is often captured and piped to drinkers which reduces or eliminates the water available to support riparian and aquatic resources at the source. Livestock use at undeveloped seeps and springs can also damage water-dependent resources through trampling and grazing. The current trend when developing water sources is to use eco-friendly spring boxes that ensure some water remains at the source to support water-dependent resources. A trend towards increased fencing of these resources also reduces damage. Other trends would be similar to those described for “Seeps and Springs” above.

Groundwater-dependent Ecosystems

This assessment is based on the potential for groundwater development upstream of perennial and intermittent streams to reduce groundwater discharge to these resources. Areas with potential for reduced groundwater discharge include areas below mines and developing private lands.

Trends are towards reduced groundwater discharge and may be compounded by altered precipitation patterns anticipated from climate change.

Aquatic Habitat and Biota

Risks to aquatic habitat and biota result from habitat fragmentation, dewatering, water quality impacts (discussed previously), and particularly competition and predation from nonnative aquatic species when present, such as green sunfish, bullfrogs, and crayfish. Risks are based on an assessment of these factors.

Road Impacts

Risks from road impacts are generally greater near urban areas and lower in more remote areas. Areas with large amounts of wilderness such as the Lower Verde and Lower Salt subbasins support substantial number of subwatersheds with low road impact risks. The Camp Creek-Verde River and Sycamore Creek watersheds are heavily impacted by roads due to proximity to the Phoenix metropolitan area despite occupying a portion of the Lower Verde subbasin.

The trend of road impacts should be down over time as the Travel Management Rule is implemented. Proliferation of new routes should decline and once existing routes identified for decommissioning are decommissioned the impacts of roads should decline.

Chapter 7. At-risk Species

Identifying and Assessing At-risk Species in the Plan Area

This section of the assessment focuses on identifying those species that are federally recognized as threatened, endangered, proposed, and candidate species as well as potential "species of conservation concern." This section also documents information gaps relevant to at-risk species that may be filled through inventories, plan monitoring, and research. Other species of interest on the Tonto National Forest such as popular game species are addressed in Volume II, "Multiple Uses."

Under the National Forest Management Act (16 U.S.C. 1604(g)(3)(B)), the Forest Service is directed to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet multiple-use objectives, and within the multiple-use objectives of a land management plan adopted pursuant to this section [of this Act], provide, where appropriate, to the degree practicable, for steps to be taken to preserve the diversity of tree species similar to that existing in the region controlled by the plan." In order to meet this objective, the 2012 Planning Rule adopted a complementary ecosystem and species-specific relational process known as a coarse-filter/fine-filter approach to maintaining species diversity (36 CFR 219.9).

The premise behind the coarse-filter/fine-filter approach is that native species evolved and adapted within the limits established by natural landforms, vegetation, and disturbance patterns prior to extensive human alteration. Therefore, maintaining or restoring ecological conditions and functions similar to those under which native species have evolved offers the best assurance against losses of biological diversity and maintains habitats for the majority of species in an area. However, for some species, the coarse-filter alone may not be adequate, either because the reference condition is not achievable or because of nonhabitat risks to species viability.

The coarse-filter/fine-filter approach recognizes that, for many species, additional specific habitat needs or ecological conditions may be required and these may not be met by the coarse-filter alone. To determine which wildlife and plant species may require fine-filter components in addition to coarse-filter components, the Tonto National Forest has identified federally threatened, endangered, proposed, and candidate species and developed a list of potential species of conservation concern known to occur, or with the potential to occur, in the plan area. While this list itself will not become part of the forest plan, it will be used at later stages of the plan revision process to inform and ensure that specific plan components are developed to provide species diversity in the plan area. Maintaining species that are vulnerable to decline in the planning unit will maintain the biotic diversity of the unit and will therefore comply with the diversity requirement in the National Forest Management Act.

Plant and animal species are frequently a function of physical conditions and community composition of ecosystems. Specific physical conditions, created by local soil, air, water, aspect, elevation, precipitation, presence of prey, competitive or predatory species, create areas that are favorable or unfavorable to a given species. The most important direct drivers of the loss of biodiversity are habitat alterations (such as land use changes, physical modification of rivers, or water withdrawals), habitat fragmentation, climate change, invasive species, overexploitation, and pollution (MAB 2005). Therefore, this chapter builds on the reference and current conditions for the other resources assessed in this volume. It also relies heavily on the description of vegetation types in Chapter 3 (ecological response units) on the Tonto National Forest and the associated risk assessment performed.

The Tonto National Forest has six ranger districts and eight federally designated wilderness areas ranging in community types from Sonoran desert to juniper woodlands and ponderosa pine along the Mogollon Rim. The Tonto is home to hundreds of animal, plant, and fungi species. The diverse regions of both desert mountain ranges (the Superstition Mountains in the southeast), and forested areas (the Sierra Ancha Mountains in the northeast) reflect a variety of habitats, flora, and fauna. These habitat differences are the basis for unique, endemic species found only on the Tonto National Forest. For a few species, changing land use patterns outside the Tonto have reduced potential habitat availability and increased their reliance on Tonto National Forest-managed lands.

Identifying At-risk Species

Guidance for identifying species at risk is provided by the Land Management Planning Handbook, Chapter 10 – The Assessments (Forest Service Handbook 1909.12). There are two main categories of at-risk species. They are:

1. federally recognized threatened, endangered, proposed, and candidate species; and
2. potential species of conservation concern.

Identification of at-risk species on the Tonto National Forest is accomplished in cooperation with numerous Federal, State, and Tribal agencies along with various academic and nongovernmental organizations using the best available scientific information

Federally Recognized Species on the Tonto National Forest

The Endangered Species Act (16 U.S.C. Sec. 1531-1544), implemented by the Department of the Interior, U.S. Fish and Wildlife Service in the planning area, recognizes imperiled species and provides for their protection and recovery. There are 22 federally protected species on the Tonto National Forest. Of these, 6 are threatened status species (Mexican spotted owl, yellow-billed cuckoo, Chiricahua leopard frog, narrow-headed and Northern Mexican garter snakes, and Gila trout) and 12 are endangered status species (Southwestern willow flycatcher, Yuma Ridgeway's rail, loach minnow, desert pupfish, spikedace, Gila chub, Gila topminnow, razorback sucker, Arizona cliffrose (*Purshia subintegra)*, Arizona hedgehog cactus (*Echnocereus triglochidiatus var. ariznicus*), lesser long-nosed bat and ocelot (see table 110, U.S. Fish and Wildlife Service 2016). There are 2 endangered species with experimental non-essential status (Mexican wolf and the Colorado pikeminnow). Finally, 2 federally proposed threatened status species (headwater chub and roundtail chub) are present on the Tonto. At present, there are no candidate species listed in the planning area.

Section 4 of the Endangered Species Act requires the U.S. Fish and Wildlife Service to identify and protect all lands, water, and air necessary to recover an endangered species, federally designated as critical habitat. Critical habitat includes areas determined necessary for life processes of a species, including space for individual and population growth and for normal behavior. This includes cover or shelter, food, water, air, light, minerals or other nutritional or physiological requirements, sites for breeding and rearing offspring, and habitats protected from disturbances or representative of the historical geographical and ecological distributions of a species. For information on critical habitat designations by species, see table 110)

Table 110. Federally listed threatened or endangered species that are relevant to the plan area

Scientific Name	Common Name	Federal Status	Critical Habitat on Tonto National Forest Designated by the U.S. Fish and Wildlife Service
Lithobates chiricahuensis	Chiricahua leopard frog	Threatened	Critical habitat present, primarily in the northern portions of Gila and Yavapai Counties along the Mogollon Rim and Verde River (U.S. Fish and Wildlife Service 2012).
Coccyzus americanus occidentalis	Yellow-billed cuckoo	Threatened	Critical habitat proposed. Known locations of this species on the Tonto National Forest near Roosevelt Lake.
Empidonax traillii extimus	Southwestern willow flycatcher	Endangered	Critical habitat present. Numerous known locations of this species on the Tonto National Forest. Two areas around Roosevelt Lake thought to be the second highest population concentration of this species.
Strix occidentalis lucida	Mexican spotted owl	Threatened	Critical habitat present. Several nests sites on the Tonto National Forest. Some sites lost due to large fires.
Rallus obsoletus yumanensis	Yuma Ridgeway's rail	Endangered	No. Only 30 acres of potentially suitable habitat are known to occur on the Tonto National Forest
Ptychocheilus lucius	Colorado pikeminnow	Endangered, experimental population, non-essential	No (NatureServe 2015b, U.S. Fish and Wildlife Service 1985 and 1994)
Cyprindon macularius	Desert pupfish	Endangered	No (U.S. Fish and Wildlife Service 1986)
Gila intermedia	Gila chub	Endangered	Critical habitat present on western boundary of the Tonto National Forest, Agua Fria River, and tributaries (U.S. Fish and Wildlife Service 2005) (NatureServe 2015f)
Oncorhynchus gilae	Gila trout	Threatened	No (NatureServe 2015h, U.S. Fish and Wildlife Service 2006).
Poeciliopsis occidentalis occidentalis	Gila topminnow	Endangered	No (NatureServe 2015g, U.S. Fish and Wildlife Service 1967, 2007).
Tiaroga cobitis	Loach minnow	Endangered	Critical habitat on northwestern and far eastern boundaries of the Tonto, Fossil Creek, and upper Salt River. Species recently reintroduced to Fossil Creek (NatureServe 2015j, U.S. Fish and Wildlife Service 2012).
Xyrauuchen texanus	Razorback sucker	Endangered	Critical habitat mostly in north zone, Tonto Creek, and Verde River watersheds. Also in upper Salt River in central planning area (NatureServe 2015l, U.S. Fish and Wildlife Service 1991).
Meda fulgida	Spikedace	Endangered	Critical habitat on northwestern and far eastern boundaries of the Tonto, Fossil Creek, and upper Salt River. Species recently reintroduced to Fossil Creek (NatureServe 2015j, U.S. Fish and Wildlife Service 2012).

Scientific Name	Common Name	Federal Status	Critical Habitat on Tonto National Forest Designated by the U.S. Fish and Wildlife Service
Gila nigra	Headwater chub	Proposed threatened	No (NatureServe 2015i, U.S. Fish and Wildlife Service 2015).
Gila robusta	Roundtail chub	Proposed threatened	No (NatureServe 2015m, U.S. Fish and Wildlife Service 2015).
Canus lupus baileyi	Mexican wolf	Endangered, experimental population, non-essential	Potential habitat was refined in March of 2015, being split into two categories based on the revised geographic boundaries for the expanded range of the experimental population area (Mexican gray wolf experimental population area; 809 FR 2512, January 16, 2015). Primary habitat are currently those acres of mixed conifer with aspen, pinyon-juniper live oak woodland, ponderosa pine forest types on the portion of Zone 1 of the experimental population area on the Tonto National Forest. Secondary habitat is all remaining acres of ecological response unit types except mines and water in Zone 2 of the experimental population area on the Tonto National Forest.
Leptonyycteris curasoae yerbabuenae	Lesser long-nosed bat	Endangered	No
Leopardus pardalis	Ocelot	Endangered	No. Potential habitat for ocelot was refined in coordination with the U.S. Fish and Wildlife Service in March 2015 and is based around the location on U.S. Highway 60 where a young adult male ocelot was killed by a vehicle in April 2010. Potential habitat for ocelot is defined as acres of Interior Chaparral, Madrean Encinal Woodlands, and Semi-Desert Grasslands ecological response units on the Globe Ranger District.
Purshia subintegra	Arizona cliffrose	Endangered	No
Echnocereus triglochidiatus var. ariznicus	Arizona hedgehog cactus	Endangered	No
Thamnophis rufipunctatus	Narrow-headed gartersnake	Threatened	Proposed (U.S. Fish and Wildlife Service 2013)
Thamnophis eques megalops	Northern Mexican gartersnake	Threatened	Proposed (U.S. Fish and Wildlife Service 2013)

Source: U.S. Fish and Wildlife Service 2016

Section 7 of the Endangered Species Act requires Federal agencies to ensure that actions they authorize, fund, or carry out are not likely to destroy or adversely modify designated critical habitat. Section 7 also requires that any Federal agency that carries out, permits, licenses, funds, or otherwise authorizes activities that may affect a listed species must consult with the U.S. Fish and Wildlife Service to ensure that its actions are not likely to jeopardize the continued existence of any listed species. Of the 22 federally listed species mentioned above, 20 are known to be established species on the Tonto National Forest. Survey data for the ocelot and spikedace on the Tonto are largely unavailable; therefore, we currently manage for these species due to the potential for occurrence in corresponding habitat.

Criteria for Identifying a Species of Conservation Concern

A species of conservation concern is defined in the 2012 Planning Rule as "a species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur within the plan area and for which the regional forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long-term in the plan area." The guidance provided in the final directives for the 2012 planning regulations (Forest Service Handbook 1909.12 – Land Management Planning, chapter 10) was used to develop the species of conservation concern list for the Tonto National Forest. The criteria for identifying species of conservation concern are also the criteria for identifying potential species of conservation concern and include (Forest Service Handbook 1909.12, 12.52c):[9]

Species of conservation concern criteria include:

1. The species is native to, and known to occur in, the plan area.

    A species is known to occur in a plan area if, at the time of plan development, the best available scientific information indicates that a species is established or is becoming established in the plan area. A species with individual occurrences in a plan area that are merely "accidental" or "transient," or are well outside the species' existing range at the time of plan development, is not established or becoming established in the plan area. If the range of a species is changing so that what is becoming its "normal" range includes the plan area, an individual occurrence should not be considered transient or accidental.

2. The best available scientific information indicates substantial concern about the species' capability to persist over the long term in the plan area (see Forest Service Handbook 1909.12, zero code section 07, guidance on best available scientific information).

    If there is insufficient scientific information available to conclude there is a substantial concern about the species capability to persist in the plan area over the long-term that species cannot be identified as a species of conservation concern.

    If the species is secure and its continued long-term persistence in the plan area is not at risk based on knowledge of its abundance, distribution, lack of threats to persistence, trends in habitat, or responses to management that species cannot be identified as a species of conservation concern.

Scales of Analysis

Analysis of at-risk species was conducted primarily at the plan scale, which consists of the entirety of the Tonto National Forest, bounded by its administrative boundary. All species considered were evaluated based on concerns regarding persistence in the planning area. Additionally, the local scale was used to better understand trends at the plan scale. The local scale is particularly valuable for describing departure patterns in the plan scale for a given

[9] More detailed guidance for selecting species of conservation concern is presented in chapter 10 of the directives (FSH 1909.12, 12.52).

characteristic and identifying where issues may warrant specific attention and drive forest plan components. This scale is not as likely to drive ecological need for change but may drive development of plan components. The local scale of analysis consists of 4^{th}-level watersheds. Watersheds containing less than 10 percent on the Tonto National Forest were incorporated into an adjoining 4^{th}-level watershed.

Evaluating Relevant Information for At-risk Species

Information on each species was gathered into a database from the best available scientific information from NatureServe, Arizona Heritage Data Management online Environmental Review Tool system (Arizona Game and Fish Department (AZGFD) 2016), and other sources such as scientific literature and species experts. Recent information was used to update the database such as changes in a species Federal status or new observations within the plan area. Evaluation of relevant information is integral to the forest plan revision process and included the following four-step process for identifying the at-risk species:

1. Review and screen species that are native and found in the plan area (criteria 1), and determine which species have been documented to occur on the Tonto National Forest.
2. Determine which potential species of conservation concern has best available scientific information that indicates substantial concern about the species' capability to persist over the long term in the plan area (criteria 2).
3. Associate the remaining potential species of conservation concern with current ecological condition and key ecosystem characteristics described within ecological response units for terrestrial species or within watersheds for aquatic species on each of the Tonto National Forest local scales.
4. Perform a risk assessment analysis on species relative to their associated ecological response unit.

Federally listed species are also tracked throughout this process but separate from potential species of conservation concern. Both the 2010 Planning Rule and final directives mandate the use of best available scientific information for each of the resource parameters evaluated in this assessment.

NatureServe conservation status ranks were used as an initial screening tool. NatureServe is a non-profit organization that provides high-quality scientific expertise for conservation. One of their resources, NatureServe Explorer, is a database of more than 70,000 plants, animals, and habitats of the United States and Canada. This searchable database contains species information such as conservation status, distribution, ecology, life history, management, and references. The Forest Service planning directives (Forest Service Handbook 1900.12) specify using NatureServe conservation status ranks.

NatureServe status ranks are based on a scale of one to five, ranging from critically imperiled (G1) to demonstrably secure (G5). Status is assessed and documented at three distinct geographic scales global (G), national (N), and subnational state/province (S). Intraspecific taxa (subspecies or other designations below the level of species) are indicated by "T rank." The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment report (G = global, Na = national, and S = subnational), or intraspecific (T) where appropriate. The numbers have the following meanings: 1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, and 5 = demonstrably secure.

Step 1: Identify species that are native to, and known to occur, in the plan area.

Of the more than 2,187 animal, plants, and fungi species found in Arizona (NatureServe 2016), only species with documented occurrences and potential habitats on National Forest System lands throughout Arizona were carried forward. Many species not carried forward are associated with habitats that exist elsewhere in the state but not found on the Tonto (for example, Chihuahuan Desert). For species with documented habitat on the Tonto, those that met one or more of the following criteria were considered potential species of conservation concern:

- Species with a status rank of G or T 1, 2, or G3 and S 1 or 2 on NatureServe ranking system
- Species that were removed within the past 5 years from the Federal list of threatened or endangered species and other delisted species the regulatory agency still monitors. No species on the Tonto National Forest were removed from the list of federally threatened or endangered species within the past 5 years. Two species, bald eagle and American peregrine falcon, are still monitored for impacts of any actions on the Tonto.
- Species listed under a special status or conservation concern by relevant States, or federally recognized Tribes. Information for the State of Arizona was derived from Arizona Game and Fish Department and the species listed as threatened or endangered by adjacent White Mountain Apaches (no species were identified as threatened or endangered by the Tribe).
- Species identified by Federal, State, federally recognized Tribes as high priority for conservation (some plant species were identified by the White Mountain Apache Tribe)
- Species identified as species of conservation concern in adjoining National Forest System plan areas. Species on the adjoining Coconino and Apache-Sitgreaves National Forests are the same as those on the Forest Service Southwest Regional Forester’s sensitive species list (USDA Forest Service 2013b).
- Species identified as recently delisted or have a positive 90-day finding in Arizona by the U.S. Fish and Wildlife Service (77 FR 69994)
- Species identified as those of the greatest conservation need by the Arizona State Wildlife Action Plan (SWAP 2012) and Arizona Rare Plant Technical Council
- Species for which the best available scientific information indicates there is local conservation concern about the species' capability to persist over the long-term in the plan area due to:
    - significant threats, caused by stressors on and off the plan area, to populations or the ecological conditions they depend upon (habitat). These threats include climate change.
    - declining trends in populations or habitat in the plan area;
    - restricted ranges (with corresponding narrow endemics, disjunct populations, or species at the edge of their range); and
    - low population numbers or restricted ecological conditions (habitat) within the plan area.

The next part of step 1 involved identifying which of these species occurs on the Tonto National Forest (FSH 1909.12, 12.52c (1)). Where possible, published location information was used to filter out species that were not reported in one of the four counties (Gila, Maricopa, Yavapai, Pinal) encompassing the Tonto or with more precise documented locations not on the national forest (shown in table 111 on page 333). From the initial list of 2,187 potentially at-risk species occurring in Arizona, 63 plant species and 99 wildlife species have been documented to occur on the Tonto National Forest (162 total species).

Internal databases; Natural Resources Manager (USDA Forest Service 2015); on-line and museum databases, including Arctos Collection Management Information System (ARCTOS 2014), Butterflies and Moths of North America 2014, Natural Heritage Arizona (HDMS 2015), Rocky Mountain Bird Observatory (RMBO 2014), and Southwest Environmental Information Network (SEINet 2016); and unpublished breeding bird survey data (USDA Forest Service 2012) were queried for Tonto National Forest-specific documented locations of observations.

In addition to the databases and lists cited above, Forest Service biologists at the Tonto National Forest supervisor's office, each of the ranger districts, and the Southwestern regional office consulted in the development of the potential species of conservation concern list. Subject matter experts at the U.S. Fish and Wildlife Service, Arizona Game and Fish Department, researchers, and others were consulted; they were able to consult internal records and databases or rely on expert knowledge to further filter the list. Subject matter experts were consulted via publications or personal communications and included staff from Arizona Game and Fish Department (Sabra Tonn, C. Akins, B. Burger, T. Corman, K.Wolff-Krauter, K. Jacobson E. Juarez, A. McIntire, J. Sorenson, C. Gill, T. Robinson); Northern Arizona University (C. Chambers); U.S. Fish and Wildlife Service (G. Beatty, J. Servos, K. Robertson); U.S. Forest Service (K. Kennedy); Arizona State University (L. Makings, W. Fertig) and the Desert Botanical Garden (W. Hodgson, A. Salywon).

The Arizona Rare Plant Advisory Group – The scarce funding for plant conservation and the small number of field botanists regionally make prioritizing plant conservation particularly difficult in the Southwest. Additionally, many areas in the region and on the Tonto National Forest are largely unsurveyed. While the Arizona Game and Fish Department's Heritage Data Management System provides exemplary information on rare plants, the lack of statutory authority concerning native plants restricts the employment of botanical experts to assist in the management of rare plant information (Laurenzi and Spence 2013). The current NatureServe ranking system has become more robust, considering key criteria such as long-term and short-term trends, area of occupancy, condition of occurrences, intrinsic rarity, and threats (Regan et al. 2004).

In an attempt to overcome these shortcomings, a regional assessment of critically imperiled to imperiled plant species was conducted by the Southwest Rare Plant Task Force, led by Laurenzi and Spence (2013). All NatureServe ranked G1, G2, T1, and T2 species for the state of Arizona were queried and checked against a previous list generated from the 2006 Southwestern Rare Plant Taskforce workshop. The final list consisted of 176 species that were carried forward in their analysis. The "Wyoming Protocol" (Fertig 2012) was used in determining conservation priority rankings for each species (very high concern, high concern, watch, likely secure, need data and peripheral). Seven key criteria were assessed for each species: distribution, number of populations, number of individuals, habitat specificity (generalist or specialist), intrinsic rarity, magnitude of threats and population trends. Species were assessed and scored from a number of botanists and experts with State (Arizona Game and Fish Department) and Federal agencies and local conservation organizations (Desert Botanical Garden). This list was further updated in 2014, and led to the development of the Arizona Rare Plant Advisory Group sensitive plant list and is continually being revised. This list was referenced in the evaluation of at-risk plant species.[10]

[10] http://www.aznps.com/documents/NPLPAGNPLPAG_Final_June2014.pdf

Walter Fertig, assistant curator and botanist, at the Arizona State University Herbarium, generously provided input and feedback on a number of considered at-risk plant species for the Tonto National Forest at-risk species assessment.

Other sources used to evaluate relevant at-risk information for species of conservation concern included:

- Arizona Heritage Data Management System element abstracts and Arizona's Online Environmental Review Tool (Arizona Game and Fish Department 2016)
- The Southwest Environmental Information Network (SEINet)
- Heritage Data Management System species' abstracts
- Arizona Rare Plant Field Guide 2000
- Viability Analyses for Vascular Plant Species within Prescott National Forest, Arizona (Baker 2011)

The Arizona State Wildlife Action Plan was updated in 2012, to reflect recent knowledge and status of species. Some species in the plan did not meet the NatureServe ranking criteria for species of conservation concern, thus reducing the number of species to be considered. For highly visible and high-interest species (such as birds), reliable collection and observation data are available.

While compiling relevant species information, there were several sources of data that appeared to fill gaps for best available scientific information. Citizen science in conservation allows volunteers to collect and submit data to online databases including eBird (2015), iNaturalist (2015), and BugGuide.Net (2015). These resources were used to determine presence or absence in the planning area by getting reliable location data where it was possible to verify observations.

For many other species, some information is simply not available. In some cases, it was not possible to determine if this was because surveys had been conducted but the species was not found (negative surveys) or surveys had not been conducted at all. For example, there are 13 spring snails identified by Arizona Game and Fish Department in the state, but these animals occupy small spring complexes with few surveys completed statewide and even fewer with repeat survey information (Sorensen 2016). No fungi or lichen species were carried forward because no survey information exists to verify if those identified as potentially at-risk occur on the Tonto National Forest. These are data gaps that should be addressed through future inventories, plan monitoring, or research. During the assessment, other data gaps were found and attributed mainly to inadequate survey data. For example, a terrestrial snail species, the Sierra Ancha talussnail (*Sonorella anchana*), has only one known recorded measurement in 1949, with no known successful surveys conducted since (U.S. Fish and Wildlife Service 2009, NatureServe 2015o).

Of the 162 identified at-risk species that were identified as occurring on the Tonto National Forest there are 5 mammals, 76 birds, 6 amphibians and reptiles, 8 invertebrates, 4 fish, and 63 plants. The species carried forward, rationale for consideration, Nature Serve ranking and documentation of occurrence are provided in table 111.

In addition to the Nature Serve ranking, rationale for consideration includes:

- NPL: State status for native plants (Arizona Native Plant Law and Antiquities Act)
- AZR: Arizona Rare Plant List from the Arizona Rare Plant Taskforce (2014)
- SGCN: Species of greatest conservation need in Arizona's State Wildlife Action Plan

- BCC: USFWS birds of conservation concern (2008).
- BLM: BLM sensitive species list
- F: Federally delisted within last 5 years
- LC: Local conservation concern through expert opinion
- N: NatureServe Global, Taxonomic, National, or Subnational Ranking
- RF: Southwest Regional Forester's sensitive species list 2013
- FWS: A positive 90-day finding by the U.S. Fish and Wildlife Service

Table 111. Possible species on the Tonto National Forest (NF) available for consideration as species of conservation concern

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Birds				
Accipiter gentilis	Northern goshawk	BLM, SGCN, LC, RF	G5 S3	eBird
Aechmophorus clarkii	Clark's grebe	SGCN, LC	G5 S3	eBird
Aechmophorus occidentalis	Western grebe	SGCN, LC	G5 S3	eBird
Aix sponsa	Wood duck	N	G5 S2B,S3N	eBird
Ammodramus savannarum	Grasshopper sparrow	BLM, SGCN, N, RF	G5 S1S2	eBird
Anas acuta	Northern pintail	N	G5 S2B,S5N	eBird
Anas americana	American wigeon	N	G5 S1B,S5N	eBird
Anas clypeata	Northern shoveler	N	G5 S1B,S5N	eBird
Anas discors	Blue-winged teal	N	G5 S2B,S5N	eBird
Anthus rubescens	American pipit	N	G5 S2B,S5N	eBird
Antrostomus arizonae	Mexican whip-poor-will	LC	GNR S4	eBird
Aquila chrysaetos	Golden eagle	BLM, SGCN	G5 S4	eBird
Ardea alba	Great egret	N	G5 S1B,S4N	eBird
Asio otus	Long-eared owl	SGCN	G5 S2B,S3S4N	eBird
Aythya valisineria	Canvasback	N	G5 S1B,S4N	eBird
Branta canadensis	Canada goose	N	G5 S1B,S4N	eBird
Bubulcus ibis	Cattle egret	N	G5 S1B,S4N	eBird
Buteo regalis	Ferruginous hawk	BLM, SGCN	G4 S2B,S4N	eBird
Buteogallus anthracinus	Common black hawk	N, SGCN, BCC, RF	G4G5 S3B	eBird
Calamospiza melanocorys	Lark bunting	N	G5 S1B, S5N	eBird
Calypte costae	Costa's hummingbird	SGCN	G5 S5	eBird
Camptostoma imberbe	Northern beardless-tyrannulet	SGCN, RF	G5 S4	eBird
Cardellina rubrifrons	Red-faced warbler	SGCN, LC	G5 S4	eBird

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Catharus ustulatus	Swainson's thrush	SGCN, N	G5 S1B	eBird
Chordeiles minor	Common nighthawk	SGCN	G5 S5B	eBird
Cinclus mexicanus	American dipper	SGCN, LC	G5 S3	eBird
Circus cyaneus	Northern harrier	N	G5 S1S2B,S5N	eBird
Cistothorus palustris	Marsh wren	SGCN, N	G5 S2B,S3S4N	eBird
Colaptes chrysoides	Gilded flicker	BLM, SGCN, LC	G5 S5	eBird
Contopus cooperi	Olive-sided flycatcher	SGCN, N	G4 S2B	eBird
Cynanthus latirostris	Broad-billed hummingbird	SGCN, RF	G5 S3	eBird
Egretta thula	Snowy egret	SGCN, N	G5 S2B,S4N	eBird
Empidonax hammondii	Hammond's flycatcher	N	G5 S1B,S2S3N	eBird
Empidonax occidentalis	Cordilleran flycatcher	SGCN	G5 S2S3B	eBird
Eugenes fulgens	Magnificent hummingbird	SGCN	G5 S4	eBird
Falco mexicanus	Prairie falcon	SGCN, BCC	G5 S4	eBird
Falco peregrinus	American peregrine falcon	BLM, SGCN, RF	G4T4 S4	eBird
Gallinago delicata	Wilson's snipe	N	G5 S1B,S4N	eBird
Geothlypis tolmiei	MacGillivray's warbler	SGCN	G5 S2S3B,S4M	eBird
Glaucidium gnoma	Northern pygmy owl	SGCN	G4G5 S4	eBird
Gymnorhinus cyanocephalus	Pinyon jay	SGCN, BLM, BCC	G5 S5	eBird
Haliaeetus leucocephalus pop. 3	Bald eagle	BLM, N, RF	G5 S2S3	eBird
Himantopus mexicanus	Black-necked stilt	N	G5 S2	eBird
Icterus bullockii	Bullock's oriole	SGCN, N	G5 S4B,S1N	eBird
Junco phaeonotus	Yellow-eyed junco	SGCN, RF	G5 S3	eBird
Lophodytes cucullatus	Hooded merganser	N	G5 S2N	eBird
Megaceryle alcyon	Belted kingfisher	N	G5 S2B,S5N	eBird
Melanerpes lewis	Lewis's woodpecker	SGCN	G4 S4	eBird
Melanerpes uropygialis	Gila woodpecker	SGCN	G5 S5	eBird
Melozone aberti	Abert's towhee	SGCN, RF	G3G4 S3	eBird
Melozone fusca	Canyon towhee	BCC	G5 S5	eBird
Micrathene whitneyi	Elf owl	SGCN	G5 S5	eBird
Myiarchus tuberculifer	Dusky-capped flycatcher	SGCN	G5 S4	eBird
Myiodynastes luteiventris	Sulphur-bellied flycatcher	SGCN, LC, RF	G5 S3	eBird

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Oreothlypis luciae	Lucy's warbler	SGCN	G5 S5	eBird
Pandion haliaetus	Osprey	N	G5 S2B,S4N	eBird
Passerella iliaca	Fox sparrow	N	G5 S2N	eBird
Patagioenas fasciata	Band-tailed pigeon	SGCN	G5 S4	eBird
Peucedramus taeniatus	Olive warbler	SGCN, LC	G5 S4	eBird
Phainopepla nitens	Phainopepla	SGCN	G5 S5	eBird
Phalaropus tricolor	Wilson's phalarope	N	G5 S1B,S5N	eBird
Plegadis chihi	White-faced Ibis	N	G5 S2S3N	eBird
Phalacrocorax brasilianus	Neotropic cormorant	N	G5 S1N	eBird
Progne subis arboricola	Western purple martin	N	G5 S2	Arizona Breeding Bird Atlas
Progne subis hesperia	Desert purple martin	BLM, SGCN	G5T4 S2S3B	eBird
Setophaga graciae	Grace's warbler	SGCN, LC	G5 S5	eBird
Setophaga nigrescens	Black-throated gray warbler	SGCN	G5 S5	eBird
Setophaga petechia	Yellow warbler	SGCN	G5 S4	eBird
Setophaga townsendi	Townsend's warbler	N	G5 S4M,S1S2N	eBird
Spinus lawrencei	Lawrence's goldfinch	N	G3G4 S1S3N	eBird
Spizella atrogularis	Black-chinned sparrow	SGCN	G5 S5	eBird
Toxostoma bendirei	Bendire's thrasher	SGCN, N	G4G5 S4	eBird
Troglodytes pacificus	Pacific wren	N	G5 S1B,S2N	eBird
Vireo bellii	Arizona Bell's vireo	SGCN	G5 S4	eBird
Vireo vicinior	Gray vireo	SGCN, RF	G4 S4	eBird
Zonotrichia leucophrys	White-crowned sparrow	N	G5 S1B,S5N	eBird
Fish				
Agosia chrysogaster chrysogaster	Gila longfin dace	SGCN, BLM	G4T3T4, S3S4 (NatureServe, 2015k)	(AGFD, 2013a)
Catostomus insignis	Sonora sucker	SGCN, RF, BLM	G3G4, S3 (NatureServe, 2015n)	(AGFD, 2002g)
Rhinichthys osculus	Speckled dace	SGCN, BLM	G5, S3S4 (NatureServe, 2015q)	(AGFD, 2002f)
Catostomus clarkii	Desert sucker	SGCN, RF, BLM	G3G4, S3S4 (NatureServe, 2015c)	(AGFD, 2002b)
Invertebrates				

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Danaus plexippus pop. 1	Monarch butterfly	FWS	G4T2T3, SNRB	Morris et al. 2015
Fallceon eatoni	A mayfly	N, RF	G1G2, SNU SR(NatureServe 2015d)	Salt River Canyon (NatureServe 2015d)
Pyrgulopsis simplex	Fossil springsnail	SGCN, RF, N, S, BLM	G1G2, S1 (NatureServe 2015e)	Fossil springs surveys, USFS
Sonorella allynsmithi	Phoenix (Squaw Peak) talussnail	N, SGCN, LC	G1, S1 (NatureServe, 2015p)	(AGFD, 2015c; Waters, 2011)
Sonorella anchana	Sierra Ancha talussnail	N, SGCN, LC	G1,SH (NatureServe, 2015o)	(USFWS, 2009)
Wormaldia planae	A caddisfly	N, RF	G2, SNU SR (NatureServe, 2015r)	Fossil Creek
Agathon arizonicus	Net-winged midge	RF	G1, SNU (NatureServe, 2015a)	Workman Cr., Sierra Ancha Mtns (AGFD, 2003; USFWS, 2009)
Cylloepus parkeri	Parker's cylloepus riffle beetle	RF	G1, S1	Found in Bloody Basin within Tonto FS (AGFD, 2003b; USFWS, 2009)
Mammals				
Corynorhinus townsendii pallescens	Pale Townsend's big-eared bat	SGCN, RF	G3G4T3T4 S3S4	Recorded observations in 11 mine adits in 2015-2016 on the Tonto NFBat Conservation International contracted through Tonto NF
Euderma maculatum	Spotted bat	SGCN, RF	G4, S2S3	Above the rim in other areas of the country found in sagebrush steppe desert areas; HDMS
Idionycteris phyllotis	Allen's big-eared bat	SGCN, RF	G4, S2S3	HDMS
Lasiurus blossevilli	Western red bat	RF, N	G5, S3	HDMS
Macrotus californicus	California leaf-nosed bat	SGCN	G4 S3	HDMS
Plants				
Abutilon parishii	Pima Indian mallow	NPL, BLM, RF	G3 S3	SEINet 2016
Acacia farnesiana	Sweet acacia		G5 S2SE3	SEINet 2016
Agastache rupestris	Baboquivari threadleaf giant hyssop		G3? S2	SEINet 2016
Agave delamateri	Tonto Basin agave	NPL, AZR, RF	G2 S2	SEINet 2016
Agave murpheyi	Hohokam Agave	NPL, BLM, RF	G2 S2?	SEINet 2016

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Agave phillipsiana	Grand Canyon century plant	NPL, RF	G1? S1	SEINet 2016
Agave toumeyana var. *bella*	Toumey agave	NPL	G3T3 S3	SEINet 2016
Agave toumeyana var. *toumeyana*	Toumey agave	NPL	G3T3 SNR	SEINet 2016
Allium bigelovii	Bigelow onion	NPL	G3 S2S3	SEINet 2016
Carex chihuahuensis	Chihuahuan sedge	AZR, RF	G3G4 S2S3	SEINet 2016
Carex ultra	Arizona giant sedge	AZR, BLM, RF	G3? S2	SEINet 2016
Cimicifuga arizonica	Arizona bugbane	NPL, AZR, RF	G2 S2	SEINet 2016
Cirsium parryi ssp. *mogollonicum*	Mogollon thistle	AZR, LC	G4T3 S3	SEINet 2016
Colubrina californica	California snakeweed		G4 S2S3	SEINet 2016
Crataegus rivularis	River hawthorn		G5 S1	SEINet 2016
Desmodium metcalfei	Metcalfe's tick-trefoil	AZR, RF	G3G4 S3	SEINet 2016
Dieteria bigelovii var. mucronata	Bristle-tipped aster		G4G5T2 S3	SEINet 2016
Dryopteris arguta	Western shield fern		G5 S2	SEINet 2016
Epilobium foliosum	Leafy Willow Herb		G5 S2	SEINet 2016
Eremogone aberrans (Arenaria aberrans)	Mt. Dellenbaugh sandwort	AZR, RF	G2 S2	SEINet 2016
Erigeron anchana	Sierra Ancha fleabane	AZR, RF	G2 S2	SEINet 2016
Erigeron arisolius	Arid Throne fleabane	AZR, LC	G2 S2	SEINet 2016
Erigeron hodgsoniae	Hodgson's fleabane	LC	Not Ranked	SEINet 2016
Erigeron piscaticus	Fish Creek fleabane	NPL, BLM, RF	G1 S1	SEINet 2016
Erigeron pringlei	Pringle's fleabane	AZR	G2 S2	SEINet 2016
Eriogonum ripleyi	Ripley wild buckwheat	NPL, AZR, RF	G2 S2	SEINet 2016
Fremontodendron californicum	California flannel bush	NPL, AZR, BLM	G4 S2S3	SEINet 2016
Galium collomiae	Fossil Hill Creek bedstraw	LC	G3 S3	SEINet 2016
Hedeoma dentata (Hedeoma dentatum)	Arizona mock-pennyroyal		G3 S3	SEINet 2016
Heuchera eastwoodiae	Senator mine alumroot	AZR, RF	G3 S3	SEINet 2016
Heuchera glomerulata	Chiricahua Mountain alumroot	RF	G3 S3	SEINet 2016

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Hymenoxys ambigens var. *ambigens*	Pinaleno Mountain rubberweed	AZR, RF	G3?T1? S1?	SEINet 2016
Hymenoxys jamesii	James' rubberweed	AZR	G2G3 S2S3	SEINet 2016
Justicia candicans	Hierba azul		G4 S2	SEINet 2016
Limonium limbatum	Marsh rosemary		G4 S1	SEINet 2016
Lotus alamosanus	Alamos deer vetch		G3G4 S1	SEINet 2016
Lotus mearnsii var. *equisolensis*	Horseshoe deer vetch	AZR, RF	G3T1 S1	SEINet 2016
Lotus mearnsii var. *mearnsii*	Mearns' bird's-foot trefoil		G3T3 S3	SEINet 2016
Lupinus latifolius ssp. *leucanthus*	Broadleaf lupine	AZR, RF	G5T1T2 S1	SEINet 2016
Mabrya acerifolia	Mapleleaf false snapdragon	AZR, RF	G2 S2	SEINet 2016
Machaeranthera arida	Arid tansy-aster		G3G4 S3	SEINet 2016
Myosurus nitidus	Western mousetail	AZR	G2G4 S2	SEINet 2016
Osmorhiza brachypoda	Sweet cicely	RF	G4 S2	SEINet 2016
Packera neomexicana var. toumeyi (Senecio n. var. t.)	Toumey groundsel	AZR, RF	G5T2Q S2	SEINet 2016
Pediomelum verdiensis	Verde breadroot	AZR, RF	G1 S1	SEINet 2016
Penstemon nudiflorus	Flagstaff beardtongue	AZR, RF	G2G3 S2S3	SEINet 2016
Perityle gilensis var. *gilensis*	Gila rock daisy	AZR, RF	G2? T2? S2?	SEINet 2016
Perityle gilensis var. *salensis*	Salt River rock daisy	AZR, RF	G2? T2? S2?	SEINet 2016
Perityle saxicola	Fish Creek rock daisy	AZR, RF	G1? S1	SEINet 2016
Phacelia crenulata var. *corrugata*	Cleftleaf scorpion-weed		G5TNR S2S3	SEINet 2016
Phlox amabilis	Arizona phlox	AZR, RF	G2G3 S2S3	SEINet 2016
Phlox cluteana	Navajo Mountain phlox		G3 S2	SEINet 2016
Plagiobothrys pringlei	Pringle's popcorn-flower		G3G4 S2	SEINet 2016
Polystichum scopulinum	Mountain hollyfern		G4 S2	SEINet 2016
Polygala rusbyi	Rusby's milkwort	RF	G3 S3	SEINet 2016
Rubus leucodermis	Westerns raspberry		G5 S3	SEINet 2016
Rumex orthoneurus	Blumer's dock	NPL, AZR, RF	G3 S3	SEINet 2016
Salvia amissa	Aravaipa sage	AZR, BLM, RF	G2 S2	SEINet 2016

Scientific Name	Common Name	Rationale for Consideration[1]	NatureServe rank	Documentation of Occurrence
Salvia davidsonii	Davidson sage		G2? S2?	SEINet 2016
Sphaeralcea rusbyi	Rusby's globemallow	LC	G4 SNR	SEINet 2016
Thelypteris puberula	Showy maiden fern		G5 S2	SEINet 2016
Thelypteris puberula var. sonorensis	Aravaipa woodfern	AZR, BLM, RF	G5T3 S2	SEINet 2016
Triteleia lemmoniae	Oak Creek triteleia	NPL	G3 S3	SEINet 2016
Reptiles and Amphibians				
Anaxyrus microscaphus	Arizona toad	N, SGCN	G3G4, S3S4	HDMS
Aspidoscelis pai	Pai striped whiptail	SGCN	G3G4 S1	HDMS
Gopherus morafkai	Sonoran desert tortoise	SGCN, RF	G4 S4	HDMS
Lithobates yavapaiensis	Lowland leopard frog	SGCN, N, RF	G4, S3	Found on most Tonto NF RDs
Trimorphodon lambda	Sonoran lyresnake	N	G5 S2	HDMS
Xantusia bezyi	Bezy’s night lizard	SGCN,RF	G2 S2	HDMS

1. SGCN: Species of Greatest Conservation Need, NPL: State status for native plants (Arizona Native Plant Law and Antiquities Act) BLM: BLM sensitive species list, F: Federally de-listed within last 5 years, LC: Local conservation concern through expert opinion, N: NatureServe Global, Taxonomic, National, or Subnational Ranking, RF: Southwest Regional Forester’s Sensitive Species List 2013, RP: Arizona Rare Plant List 2014 from the Arizona Rare Plant Taskforce.

Step 2: Identify species that are at risk of persisting over the long term in the plan area.

The second step of the species of conservation concern analysis process determined which species can be removed from the potential species of conservation concern list because it is secure and its continued long-term persistence in the plan area is not at risk. Step 2 criteria were: (1) species populations and the ecological conditions they depend upon are not known to be affected by threats; (2) species have stable or upward trends in population or habitat; (3) species do not have restricted ranges; (4) species do not have low population numbers or restricted ecological conditions; (5) species occurrence in the planning area is considered “transient”; or (6) there is insufficient information to evaluate whether or not the species is at risk for persistence within the plan area.

Based on knowledge of the species’ abundance, distribution, lack of threats to persistence, trends in habitat, or responses to management, 111 of the initial 162 species identified as potential species of conservation concern are secure and their continued long-term persistence in the plan area is not at risk or there is insufficient information to deem them at risk. As such, these species are no longer considered for further analysis as potential species of conservation concern.

Table 112 shows the list of species removed, rationale for removing them and the planning directive criteria supporting their removal.

Table 112. Potential species of conservation concern removed from further analysis and rationale for removal

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Mammals		
Pale Townsend's big-eared bat	• Old mine adits have provided additional roosting habitat for these bats in the planning area (2). • Adit closures where bats or sign of bat use is discovered are closed with a bat-friendly gate to reduce disturbance to roosting habitat, mitigating any known threats (Bill Burger, Arizona Game and Fish Department, personal communication, 2016) (1). • Population level information is generally not available for the planning area, but numbers are not known to be affected by particular threats (6). • Aside from roosting areas, habitat is not thought to be restricted (3).	1,2,3,6
Spotted bat	• Ecological conditions for species are cracks and crevices in vertical cliffs for roosting, and open waterways for foraging. Cliffs are geological features that are not departed from reference condition and are not affected by management. Open waterways have increased on the planning unit due to impoundments and water developments (1). • Decreased foraging habitat in natural river systems may be off-set by increase in ponds and reservoirs (Chambers and Herder 2005) (3).	1,3
Birds		
Abert's towhee	• The Abert's towhee (*Melozone aberti*) is expanding its range in Arizona (Corman and Wise-Gervais 2005) (2). • This species is adaptable, thriving in suburban Phoenix and has been found nesting in tamarisk stands (Corman and Wise-Gervais 2005) (4).	2,4
American peregrine falcon	• Resident population is stable enough that the Arizona Game and Fish Department allows permitted capture for use for falconry (2). • These birds nest along cliffs, and while there is some climbing related recreation that occurs on the Tonto, nesting habitat is likely at reference condition (1). • Increases in man-made water sources has likely increased the prey base of falcons by creating additional habitat for waterfowl (2).	1,2
American pipit	• This species uses the Tonto National Forest for wintering and that population is stable with a S5N rating in NatureServe (NatureServe 2016, Corman and Wise-Gervais 2005) (2).	2
American wigeon	• The Tonto National Forest is a part of the wigeon's wintering grounds but their populations are secure with a S5N ranking in NatureServe (NatureServe 2016, Corman and Wise-Gervais 2005) (2).	2
Arizona Bell's vireo	• NatureServe shows this species as stable with ranks of G5/S4 (NatureServe 2016) (2). • Bell's vireos (*Vireo bellii arizonae*) are a very common breeder on the Tonto National Forest where they have expanded their range and increased in abundance (Corman and Wise-Gervais 2005) (3).	2,3

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Bald eagle	• Bald eagle populations in the planning area have increased over time due to the addition of large, man-made waterbodies as habitat and the introduction of sportfish as a prey base (2). • Bald eagles are widespread nationally and do not have restricted ranges (3).	2,3
Band-tailed pigeon	• The band-tailed pigeon (*Patagioenas fasciata*) is a game species and its population is managed by the state. Population numbers are sufficient for regular harvest (2).	2
Belted kingfisher	• Breeding bird atlas results show this species has great increased in central Arizona over the past two decades (Corman and Wise-Gervais 2005) (2). • Breeding bird atlas surveys show that belted kingfishers are widespread along central Arizona drainages (Corman and Wise-Gervais 2005) (3).	2,3
Bendire's thrasher	• The Tonto National Forest does not appear to be a part of the species' native range based on sightings in eBird and data from the Arizona Breeding Bird Atlas (BirdLife International 2016, eBird 2016, Corman and Wise-Gervais 2005) (5).	5
Black-necked stilt	• Black-necked stilts (*Himantopus mexicanus*) are rare visitors to the Tonto National Forest, observed only occasionally at water bodies during migration or winter. Generally, the planning area lacks suitable habitat for this shorebird, thus its occurrence in the planning area is considered transient (Sullivan et al. 2009) (5). • Black-necked stilts are globally secure and have a very large range that has been documented to be expanding in recent years (NatureServe 2016) (3). • Their wintering/migration habitat (large bodies of water) on the Tonto National Forest is not affected by known threats (1).	1,3,5
Black-throated gray warbler	• NatureServe ranks of G5/S5 show the species is stable (NatureServe 2016) (2). • The black-throated gray warbler (*Setophaga nigrescens*) is an abundant breeding species in the upper-middle elevations of the Tonto National Forest (T. Corman, personal communication, July 28, 2016) (4).	2,4
Blue-winged teal	• The Tonto National Forest is a part of the species' wintering grounds but their populations are secure with a S5N ranking in NatureServe (NatureServe 2016, Corman and Wise-Gervais 2005) (2).	2
Bullock's oriole	• The species is critically-imperiled on the non-breeding grounds, but the Tonto National Forest is not within this species' non-breeding range based on observations in eBird (Sullivan et al. 2009, eBird 2016) (2). • Bullock's orioles (*Icterus bullockii*) are common breeders with a wide range of riparian breeding habitats on the Tonto National Forest (Corman and Wise-Gervais 2005) (3).	2,3
Canada goose	• Wintering habitat (aquatic) is not under any major threats currently (1). • This species recently began to summer/breed on the ponds in the Phoenix area, so the species is likely expanding locally in both population and distribution (Sullivan et al. 2009) (2).	1,2
Canvasback	• Canvasback uses the Tonto National Forest for wintering grounds where it is actively hunted as a game species (2).	2

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Canyon towhee	• Ranking by NatureServe as G5/S5 shows the population of this species is stable and not at risk in the plan area (NatureServe 2016) (2). • The Arizona Breeding Bird Atlas stated canyon towhees were encountered commonly throughout their previously described range south of the Mogollon Rim (Corman and Wise-Gervais 2005) (3).	2,3
Cattle egret	• Cattle egret (*Bubulcus ibis*) does not breed or winter on the Tonto National Forest, transient only (T. Corman, personal communication, July 28, 2016) (5).	5
Common black hawk	• According to the Arizona Breeding Bird Atlas, the species shows a positive trend in population in southern Arizona (Corman and Wise-Gervais 2005) (2). • The Tonto National Forest is at the heart of the common black hawk's northern range (Sullivan et al. 2009) (4).	2,4
Common nighthawk	• The common nighthawk (*Chordeiles minor*) has expanded the southern limit of its range and can be found in new mountain ranges on the Tonto (Corman and Wise-Gervais 2005) (3). • With NatureServe ranks of G5/S5B, the species is globally and locally secure (NatureServe 2016) (2).	2,3
Cordilleran flycatcher	• Trends for the species' ecological response unit (Mixed Conifer - Frequent Fire) is going towards a more closed state, which is favorable for the cordilleran flycatcher (2). • Arizona Breeding Bird Atlas results found these flycatchers in most of their previously described range and in several new locations, suggesting the species is stable or increasing on the Tonto National Forest (Corman and Wise-Gervais 2005) (2).	2
Costa's hummingbird	• This species is listed as G5/S5 by NatureServe and population trends of this species show that populations are relatively stable (NatureServe 2016) (2). • The Costa's hummingbird (*Calypte costae*) is a common species found in Sonoran Desert habitat (4).	2,4
Dusky-capped flycatcher	• This species is common throughout much of its very large range and appears to be increasing in abundance in Arizona due to the fact that their range is expanding (Corman and Wise-Gervais 2005) (3). • Dusky-capped flycatchers (*Myiarchus tuberculifer)* are a recent colonizer of the Tonto National Forest. Arizona Game and Fish has documented 10 breeding sites on three mountain ranges on the Tonto National Forest (T. Corman, personal communication, July 28, 2016) (2).	2,3
Ferruginous hawk	• Ferruginous hawks occur on the Tonto National Forest, but are very rare, and considered transient in the plan area (Sullivan et al. 2009) (5).	5
Flammulated owl	• Habitat for the owls occur in a variety of ecological response units on the Tonto ranging from high to low threat of stand replacing fire. Population stability due to the variety of ecological response units the owl can inhabit on the Tonto limit risk to the species (4).	4

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Fox sparrow	• The preferred wintering habitat of this species, based on observations in eBird, appears to be the Interior Chaparral ecological response unit, which is currently at low departure and is projected to continue to be at low departure in the 100 year projection (Sullivan et al. 2009) (1). • Not much is known about their trends in population on the Tonto or Arizona in general (6).	1,6
Gila woodpecker	• NatureServe lists this species as G5/S5 in Arizona, showing the species is not under any imminent threats (NatureServe 2016) (1). • According to the Arizona Breeding Bird Atlas this species has extended its range in Arizona over the past century (Corman and Wise-Gervais 2005) (3).	1,3
Golden eagle	• Population trends appear stable throughout Arizona and the species does not appear to be at risk given its NatureServe rankings (S3B, S4N) (2). • Golden eagles are proactively managed under the Bald Eagle and Golden Eagle Protection Act (16 U.S.C. 668-668d), helping to mitigate known threats that could occur in the planning area (1).	1,2
Grace's warbler	• According to the Arizona Breeding Bird Atlas, the Grace's warbler (*Setophaga graciae*) status and distribution in the state has not changed from previous records (Corman and Wise-Gervais 2005) (2). • NatureServe has this species ranked as G5/S5 and reports that the species has expanded its range and recent population trends appear stable (NatureServe 2016) (3).	2,3
Grasshopper sparrow	• According to breeding bird survey data, both subspecies of grasshopper sparrow (*A. savannarum ammolegus, A. savannarum perpallidus*) do not breed on the Tonto National Forest (Corman and Wise-Gervais 2005). Very few winter records (3 to 4) of this species on the Tonto (Sullivan et al. 2009). This species, including the two subspecies, can be considered transient to the planning area (5).	5
Gray vireo	• The ecological response unit that gray vireos depend upon is experiencing low and moderate departure currently and low departure in the 100-year projection, suggesting this species and its habitat is secure in the plan area (1). • Gray vireo (*Vireo vicinior*) is a common species (in correct habitat) and a regular breeder on the Tonto National Forest. According to NatureServe the species appears secure in both global and subnational statuses (NatureServe 2016) (4).	1,4
Great egret	• The Arizona Breeding Bird Atlas states this species is expanding in Arizona (Corman and Wise-Gervais 2005) (3). • The aquatic habitat used by the great egret, namely man-made reservoirs, is not at risk on the Tonto National Forest (1).	1,3
Hammond's flycatcher	• Hammond's flycatcher (*Empidonax hammondii*) has not been documented breeding on the Tonto National Forest (Corman and Wise-Gervais 2005). The Tonto is also not a major wintering area for this species, as seen in the limited number of eBird reports during the non-breeding season (Sullivan et al. 2009). Hammond's flycatcher is strictly a migrant species through the Tonto National Forest (5).	5

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Hooded merganser	• Hooded merganser (*Lophodytes cucullatus*) does not breed on the Tonto National Forest (Corman and Wise-Gervais 2005). The species has been documented using the Tonto's waterways during winter, but these reports are rare (Sullivan et al. 2009). Hooded mergansers can be considered transient to the plan area (5).	5
Lark bunting	• The lark bunting (*Calamospiza melanocorys*) does not breed on the Tonto National Forest and is an irregular visitor at other times (Corman and Wise-Gervais 2005, Sullivan et al. 2009). This species can be considered a transient to the plan area (5).	5
Lawrence's goldfinch	• The Lawrence's goldfinch (*Spinus lawrencei*) is an accidental and nonregular breeder on the Tonto National Forest and a very rare visitor to the Tonto National Forest in winter (Sullivan et al. 2009). The species can be considered transient to the plan area (5).	5
Long-eared owl	• Arizona Game and Fish Department has been unable to assess status of the long-eared owl in Arizona during their statewide reassessment in 2012 state wildlife action plan (6).	6
Lucy's warbler	• NatureServe lists the Lucy's warbler (*Oreothlypis luciae*) as G5/S5 and it is a very common breeder on the Tonto National Forest (NatureServe 2016) (2). • The species occurs in a wide range of ecological response units based on the habitat codes in the Arizona Breeding Bird Atlas (Corman and Wise-Gervais 2005) (4).	2,4
Magnificent hummingbird	• According to the Arizona Breeding Bird Atlas, the magnificent hummingbird is expanding its range north above the Mogollon Rim in part due to the increased popularity of hummingbird feeders at campgrounds, summer homes, and forested residential areas (3). • Their population and range is expanding with no known major threats to the species (Corman and Wise-Gervais 2005) (1).	1,3
Marsh wren	• NatureServe has this species listed as a G5 species and S2B, S3S4N in Arizona (NatureServe 2016). This species is imperiled in its breeding range in Arizona; however, there are no breeding records. The Tonto National Forest does provide nonbreeding habitat, but during the nonbreeding season this species is only listed as "apparently secure/vulnerable" (2).	2
Mexican whip-poor-will	• Arizona Breeding Bird Atlas states the species population is stable, and there is evidence of range expansion (Corman and Wise-Gervais 2005) (2).	2
Neotropic cormorant	• NatureServe has listed this species as S1 in the state of Arizona; however, this ranking was given in 1996 (NatureServe 2016). Since then, the population of neotropic cormorants has exploded and are now the most common cormorant species in the Phoenix area (overtaking double-crested cormorant) (2).	2

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Northern beardless-tyrannulet	• The Arizona Breeding Bird Atlas shows this species has been found in most of their historical range and along new riparian drainages farther north than usual, suggesting the species is increasing in population and expanding its range northward in the state (Corman and Wise-Gervais 2005, BirdLife International 2016) (3). • NatureServe has listed this species as G5/S4 and with populations increasing there is no need for protection on the Tonto National Forest (NatureServe 2016) (2).	2,3
Northern goshawk	• The role of forest management and its effect on the population status of northern goshawks in the western U.S. is an area of active research with some contradictory findings and growing evidence that goshawks are more generalist in nature than previously presumed (Andersen et al. 2005, Beck et al. 2011, Beier and Drennan 1997, Beier and Ingraldi 2012, Beier et al. 2008, Drennan and Beier 2003, Hoffman and Smith 2003, Kennedy 1997, Moser and Garton 2009, Reich et al. 2004, Reynolds et al. 2008, Wiens et al. 2006). As such, more information is needed in order to determine the current risk to this raptor in the planning area (6).	6
Northern harrier	• The Tonto National Forest provides some wintering habitat (grasslands) but the nonbreeding range of this species is secure with its S5N ranking in NatureServe (2). • Throughout its range, the northern harrier is widespread (NatureServe 2016) (3).	2,3
Northern pintail	• Northern pintail uses the Tonto National Forest for wintering where it is actively hunted as a game species (2).	2
Northern pygmy owl	• This species has not experienced any significant declines, although trends are poorly known (NatureServe 2016) (2). • Northern pygmy owl (*Glaucidium gnoma*) is fairly widespread in Arizona, nesting across a large elevational range from 3,600 to 10,500 feet (Corman and Wise-Gervais 2005). This large elevational range also include the use of many different ecological response units across the Tonto National Forest (3).	2,3
Northern shoveler	• Northern shoveler uses the Tonto National Forest for wintering where NatureServe has it ranked as an S5N. It is actively hunted as a game species (NatureServe 2016) (2).	2
Olive warbler	• Olive warblers (*Peucedramus taeniatus*) are highly adaptive (occupy multiple ecological response units) and populations in Arizona are stable or slightly increasing (Corman and Wise-Gervais 2005). NatureServe agrees with the findings of the breeding bird surveys listing the species as G5/S4 (NatureServe 2016) (4).	4
Osprey	• The aquatic habitat this species prefers is not known to be affected by threats. (1) • The Tonto National Forest is a part of the species' wintering range where it is secure with its S4N ranking in NatureServe (NatureServe 2016) (2).	1,2
Phainopepla	• The phainopepla (*Phainopepla nitens*) is a very common and widespread species on the Tonto National Forest, with stable populations (Corman and Wise-Gervais 2005). NatureServe has this species listed as G5/S5 and not a candidate species for SCC (NatureServe 2016) (4).	4

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Pinyon jay	• The ecological response unit this species prefers is currently in moderate and low departure and the 100-year projection of those same ecological response units is predicted to be at low departure from reference conditions (1). • NatureServe has this species listed as G5/S5 showing that the populations are stable in Arizona (NatureServe 2016) (2). • Pinyon jays (*Gymnorhinus cyanocephalus*) are common breeders on the Tonto National Forest (T. Corman, personal communication, July 28, 2016) (4).	1,2,4
Prairie falcon	• Prairie falcon (*Falco mexicanus*) have not significantly changed their range distribution since the Pleistocene and their populations have been fairly stable in Arizona with good reproductive success (Corman and Wise-Gervais 2005) (2). • Prairie falcons also use a wide range of habitats (Corman and Wise-Gervais 2005) (4).	2,4
Snowy egret	• The aquatic habitat this species requires is not at risk in the plan area (1). • The species' wintering range is stable with an S4N ranking in NatureServe (NatureServe 2016) (2). • The Arizona Breeding Bird Atlas states this species is expanding in Arizona (Corman and Wise-Gervais 2005) (3).	1,2,3
Swainson's thrush	• Swainson's thrush (*Catharus ustulatus*) migrates through the Tonto National Forest. There are no breeding or wintering records (Sullivan et al. 2009, Corman and Wise-Gervais 2005) (5).	5
Townsend's warbler	• The Townsend's warbler (*Setophaga townsendi*) does not breed on the Tonto National Forest. It is mainly a migrant and a rare winter visitor (Sullivan et al. 2009, Corman and Wise-Gervais 2005). The species can be considered a migrant or transient to the plan area (5).	5
Western purple martin	• The species is being considered due to its S2S3B ranking in NatureServe; however, the site and many other bird trend sources have very little data on this bird (NatureServe 2016, Sullivan et al. 2009) (6).	6
White-crowned sparrow	• White-crowned sparrow (*Zonotrichia leucophrys*) is one of the most abundant and widespread birds in Arizona during the non-breeding season (Corman and Wise-Gervais 2005) (4).	4
White-faced ibis	• White-faced ibis (*Plegadis chihi*) migrates through the Tonto National Forest, with no breeding records. This species should be considered a transient to the Tonto (Corman and Wise-Gervais 2005, Sullivan et al. 2009) (5).	5
Wilson's phalarope	• Wilson's phalarope (*Phalaropus tricolor*) is a migrant species to the Tonto National Forest only, no breeding and wintering records (Corman and Wise-Gervais 2005, Sullivan et al. 2009) (5).	5
Wilson's snipe	• The species' wintering population is not at risk with a S4N rank (NatureServe 2016) (2).	2
Wood duck	• Wood ducks rarely use the Tonto National Forest's lakes and rivers during the nonbreeding season so the Tonto should not be considered a part of the wood duck's native wintering range, transient only (Corman and Wise-Gervais 2005) (5).	5

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Yellow warbler	• NatureServe has the status of this species as G5/S4 and breeding bird survey data shows a significant population increase in western North America (NatureServe 2016) (2). • Yellow warblers (*Setophaga petechia*) are common and widespread throughout North America. In Arizona, the yellow warbler is one of the most abundant species in riparian areas (Corman and Wise-Gervais 2005) (3).	2,3
Reptiles and Amphibians	•	
Arizona toad	• Hybridization with the more widely distributed Woodhouse toad has been identified as a potential threat to the species, especially in disturbed areas where man-made water sources have been introduced, (Schwaner and Sullivan 2009, Sullivan 1986). However, these trends vary across the toad's range, and the overall impact to the species is still unclear (Sullivan 1995). In areas where introgression and hybridization are not an issue, Arizona toad populations in the planning area and throughout Arizona appear to be stable, though documentation is lacking (AGFD 2013c). Due to the mixed reports on the impacts of hybridization and lack of other substantial threats to persistence in the planning area, the Arizona toad will not be considered a species of conservation concern at this time. (6)	6
Pai striped whiptail	• Taxonomy for this species is currently uncertain. While previously considered an independent species, recent analysis of mtDNA and morphology have suggested that three previous species (*A. arizonae, A. gypsi, A. pai*) be rescinded into a single species (Sullivan et al. 2014). Such a change in taxonomy would alter the conservation needs outlined in this assessment (6).	6
Sonoran lyresnake	• This snake is found across nearly all of southern Arizona and is likely found in most ranges in the western part of the state and widely distributed (3). • In Arizona, this snake occurs at elevations ranging from just a few hundred feet above sea level to over 5,000 feet. (Devitt et. al 2008, Taylor Cotton AZFGD 2016, Jones and Lovich 2009) (4)	3,4
Sonoran desert tortoise	• On October 5, 2015, the tortoise was removed as a candidate species; however, it continues to be managed under a formal candidate conservation agreement for which the Tonto National Forest is one of the signatory agencies. Thus, current threats are buffered by this multiagency agreement, greatly reducing population level effects on the Tonto (1). • While the long-term projection of tortoise populations are difficult to predict in the face of climate change and other risks, tortoise populations are currently considered stable (Averill-Murray and Klug 2000, U.S. Fish and Wildlife et al. 2015) (2). • While individual tortoises experience a number of threats due to urbanization, this is not occurring in the planning area (1). • The Tonto National Forest is currently home to some of the most dense populations of Sonoran desert tortoise (that is, Sugarloaf Mountain and Mazatzal Mountains) (Averill-Murray and Klug 2000) (4).	1,2,4

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Fish		
Sonora sucker	• Most current data suggest that populations are stable throughout its currently occupied habitats within the planning area and that it exhibits the ability to adapt to altered hydrologic conditions. (2) • However, this information is dated (studies from 1990) and more recent information on trends is not available for this species (AGFD 2002g) (6).	2, 6
Speckled dace	• Most recent data available indicate this species has stable populations within the planning area. (2) • However, survey data is dated (information from 2002) and more recent information on trends are not available for this species (AGFD 2002f) (6).	2, 6
Desert sucker	• Most recent data available indicate this species has stable populations within the planning area (2). • However, survey data is dated (information from 2002) and more recent information on trends are not available for this species (AGFD 2002b) (6).	2, 6
Invertebrates		
Netwing midge (*Agathon arizonicus*)	• Numerous petitions for listing have been found unwarranted as no evidence has been found showing extent of susceptibility to risk events (NatureServe 2015a; U.S. Fish and Wildlife Service 2009; AGFD 2003) (1). • Limited survey data indicates this species is a localized endemic with inherently limited range (6).	1, 6
A mayfly (*Fallceon eatoni*)	• Numerous petitions for listing have been found unwarranted as no evidence has been found showing extent of susceptibility to risk events (NatureServe 2015d; U.S. Fish and Wildlife Service 2009) (4). • Limited survey data exists (6).	4,6
A caddisfly (*Wormaldia planae*)	• Data is insufficient to determine trend or distribution; species is under review for NatureServe designation criteria (NatureServe 2015r; Stevens and Ledbetter 2014) (6).	6
Sierra Ancha talussnail (*Sonorella anchana*)	• Numerous petitions for listing have been found unwarranted as no evidence has been found showing extent of susceptibility to risk events (NatureServe 2015o; U.S. Fish and Wildlife Service 2009) (1). • Limited survey data indicates this species is a localized endemic with inherently limited range, none have been documented since the original surveys from 1948, considered possibly extirpated (6).	1, 6
Plants		
Aravaipa woodfern (*Thelypteris puberula* var. *sonorensis*)	• Aravaipa woodfern is lacking information on population trends and threats (AGFD 2004, NatureServe 2016). Surveys and research are needed to determine suitable habitat and habitat requirements on the Tonto (6).	6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Arid tansy-aster (*Machaeranthera arida)*	• Currently arid tansy-aster is known from more than 30 sites in Arizona (SEINet 2016). On the Tonto, plants are found in lower to upper Sonoran Desert scrub (Mojave Sonoran Desert Scrub and Sonora-Mohave Mixed Salt Desert Scrub ecological response units) and at saline areas near springs (SEINet 2016). Plants are not restricted to specific habitat features (low habitat specificity) (3). • Some populations have been described as locally common where found (SEINet 2016) (4). • There are no apparent threats to populations on the Tonto (1).	1,3,4
Arid throne fleabane (*Erigeron arisolius*)	• All known occurrences and habitat are described from the southeastern part of the state (sky islands) and Sonora Mexico (AGFD 2001). This site needs surveying to confirm populations exist on the Tonto (6).	6
Arizona mock-pennyroyal (*Hedeoma dentata*)	• There is conflicting information on the degree of rarity, described as relatively common and uncommon across its range (Irving 1980, Bertelsen 2000). Habitat loss from competition with grasses and other plants was thought to be a threat to the species but has not been substantiated (ADFG 2000) (6). • Plants are not restricted to specific habitat features and are found at all aspects (but often north-facing) in Semi-desert Grassland, Maderan Encinal Woodland, Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest ecological response units (3). • Additionally, this is a G3 S3 species which has more known sites and fewer threats than vulnerable (G2) or imperiled (G1) species (1).	1,3,6
Arizona phlox (*Phlox amabilis*)	• Population numbers are moderate to high with thousands of individuals noted for some populations (2). • Arizona phlox is primarily distributed north of the Tonto (most in Coconino and Yavapai Counties). Plants are found in a number of habitat types, do not appear to be restricted by specific habitat features (specific soils or substrates) and potential threats are low (3). • Surveys are needed to determine current and potential habitat on the Tonto (last documented on the national forest in 1976) Also, information on Arizona phlox response to fire, impacts of grazing and off-highway vehicle use are needed to assess species viability. Most importantly, accurate species identification is an issue as many specimens collected on the national forest are most likely misidentified (W. Hodgson and A. Salywon, Desert Botanical Garden, personal communication, 2016) (6).	2,3,6
Baboquivari threadleaf giant hyssop (*Agastache rupestris*)	• There is no information on population numbers, habitat requirements, or threats to the species (NatureServe 2016, SEINet 2015) (6). • In the planning area, this species is only known from the Mazatzal Wilderness area with populations decribed as locally frequent and ocassional (SEINet 2015) (2). • The species is found throughout a range of habitat types (Juniper Grass, Pinyon Juniper Evergreen Shrub, Ponderosa Pine - Evergreen Oak, and Madrean Encinal Woodland ecological response units) on the Tonto (3). • Populations are located in a designated wilderness area where potential impacts (such as off-highway vehicle use) are greatly minimized. Individuals are hard to get to, generally occurring on pockets of soil on rocky outcrops (Sabra Tonn, personal communication, 2016) (1).	1,2,3,6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Bigelow onion (*Allium bigelovii*)	• Bigelow onion (*Allium bigelovii*) is found at open dry rocky soils throughout southwest New Mexico, Arizona, and southeastern Nevada (AGFD 2005). Although only known on the Tonto from one site at the Tonto Basin local zone within the Mojave Sonoran Desert Scrub ecological response unit, potential habitat also includes Semi-Desert Grassland and Interior Chaparral ecological response units (3). • Information on population trends and threats to the species is unknown (AGFD 2005, NatureServe 2015) (6).	3,6
Bristle-tipped aster (*Dieteria bigelovii* var. *mucronata*)	• Bristle-tipped aster is a rare endemic to the Kaibab Plateau in northcentral Arizona (NatureServe 2016). Occurrences on the Tonto represent the southern extreme of species distribution. Additional data on this species in the planning area is limited (6). • There are no apparent threats to the species (NatureServe 2016, SEINet 2015) (1).	1,6
California flannelbush (*Fremontodendron californicum*)	• California flannelbush is considered rare in Arizona but widespread elsewhere (3). • There are no real threats for populations in Arizona. Although browsed by animals, threats are minimized as species has high reproductive output (AGFD 2005). While current conditions show moderate to high fuel loads at portions of the habitat, the species is well adapted to recurring fires with its abundant seed production, prolific sprouting and rapid growth (Pavek 1993) (1). • There are more than 30 sites on the Tonto at a range of habitat types (4).	1,3,4
California snakeweed (*Colubrina californica*)	• California snakeweed (*Colubrina californica*) is distributed throughout Sonora Mexico, southern Arizona, and southeast California. On the Tonto, populations are located in rocky slopes throughout desert-chaparral transitions (Mojave Sonoran Desert Scrub and Interior Chaparral ecological response units) (3). • Information is lacking for this species, however potential threats are development and gravel mining at washes and browsing by livestock but the magnitude and imminence of threats are unknown (AGDF 2001) (6).	3,6
Chihuahuan sedge (*Carex chihuahuensis*)	• Current taxonomy is unclear in this species due to overlapping in some of the character states distinguishing *C. chihuahuensis* sand *C. alma,* warranting further research on the species. The state status was changed from S2 to S3 based on recent information (Arizona Rare Plant Assessment 2014) (6).	6
Chiricahua Mountain alum-root (*Heuchera glomerulata*)	• This taxa is ranked as a G3S3 species and therefore is known from more sites and has less viability concern than other ranked species (G1S1, G2S2); no threats have been identified at this time (1).	1
Clefleaf scorpion-weed (*Phacelia crenulata* var*. corrugata*)	• Recent locality recorded on the Tonto, outside species' existing range. Specimen collected on the Tonto should be evaluated to confirm status (6). • Wide ranging (from Nevada to Texas) species with no apparent threats (NatureServe 2016, SEINet 2015) (3).	3,6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Fossil Hill Creek bedstraw (*Galium collomiae*)	• There is very little information on this species. Direct impacts to plants are likely minimized given the rocky habitat. Surveys and research is greatly needed to assess potential threats on the Tonto (6). • At present, however, there is no immediate concern for the species (1).	1,6
Hierba azul (*Justicia candicans*)	• Species uncommon in Arizona but geographically widespread elsewhere. Range extends from Oaxaca to Sonora Mexico and into Arizona (northern limit). Populations are located at the southern edge of the Tonto and represent the northern extreme of species range (3). • Information on life history, population status, distribution range and threats are unknown (NatureServe 2016, SEINet 2015) (6).	3,6
Leafy willow herb (*Epilobium foliosum*)	• Species uncommon in Arizona but geographically widespread. Plants are found at hillsides in pine forest (Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest ecological response units) and at edges of meadows in coniferous forest (Mixed Conifer - Frequent Fire ecological response unit) (3). • Locally common growing in wet ground and under ponderosa pine canopy (SEINet 2016). Eight of the 13 estimated sites in Arizona are located on the Tonto (SEINet 2016) (4). • Information on population trends and threats are unknown (NatureServe 2015, SEINet 2015). There is a lack of scientific information regarding the species status to determine substantial concern for the species persistence on the Tonto (6).	3,4,6
Marsh rosemary (*Limonium limbatum*)	• While there are few known sites in Arizona, and threats to the species are unknown. The majority of known sites are located in New Mexico and are considered secure (1). • Plants appear to have low habitat specificity; found at dry and moist conditions, intermittently flooded fields, dry alkaline sinks, grassland on gypsum, marshlands, clay banks, and along roadsides (3). • Currently, this species is not considered a species of conservation concern on the Tonto due to the questionable status (whether or not populations are on the Tonto) along with the lack of scientific information regarding the species status (6).	1,3,6
Mearns' bird's-foot trefoil (*Lotus mearnsii* var. *mearnsii*)	• Mearns' bird's-foot trefoil (*Lotus mearnsii* var. mearnsii) consists of two varities (*L. mearnsi*i var. *mearnsii* and *L. mearnsii* var. *equisolensis*). This variety is well distributed across Arizona and there are no apparent threats (NatureServe 2016, SEINet 2015). (3)	3
Mogollon thistle (*Cirsium parryi* ssp. *mogollonicum*)	• One occurrence shows Mogollon thistle occurring on the Tonto, but this georeference is most likely incorrect as the description describes an area further north in Coconino County (SEINet 2016). One population is located 5 miles north from the Tonto. Surveys should be conducted in the area to determine if there is suitable habitat on the Tonto (6).	6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Navajo Mountain phlox (*Phlox cluteana*)	• Given the species habitat (mostly ponderosa pine forest), potential threats include logging and forest fires but negative impacts have not been documented range-wide and on the Tonto. Grazing by sheep and horses do not appear to be negatively affecting populations (AGFD 2004, Phillips 1982) (1). • The large distance between known sites suggest of range of potential habitat types (Sonoran Desert Scrub to Ponderosa Pine Forest ecological response units). The potential range of habitat types and locally abundant populations suggest low viability concern for populations on the Tonto at this time (4). • Additionally, there is a lack of scientific information on the species status to determine species persistence on the Tonto (6).	1,4,6
Oak Creek triteleia (*Triteleia lemmoniae*)	• Oak Creek triteleia is a central Arizona endemic that ranges from Apache and Navajo counties, to Coconino County (Oak Creek, and Flagstaff and Mogollon escarpment), northern Gila County, and Yavapai County (AGFD 2004) (3). • In 1978, Fletcher determined at that time, there were no threats to the continued existence of Oak Creek triteleia (AGFD 2004) (1). • This species should be surveyed and monitored to determine population status, habitat requirements, distribution and threats (palatability unknown, but suspected plants are occasionally grazed) on the Tonto National Forest (6).	1,3,6
Pima Indian mallow (*Abutilon parishii*)	• Surveys have documented an increase in the current and potential habitat for this species from Sonoran Mexico to Bagdad, Arizona. Although still considered rare, the species is more widespread than originally thought (AGFD 2000) (3). • No real threats have been identified for populations in Arizona (AGFD 2000). Plants generally occur in steep habitat where any potential threats (trampling, livestock grazing, recreation) are greatly minimized (AGFD 2000, Lutch 2000) (1).	1,3
Pringle's popcorn-flower (*Plagiobothrys pringlei*)	• While the known distribution is restricted to central south Arizona, there are more than 40 sites in Arizona and 7 on the Tonto National Forest. Plants are found at a range of habitat types. Populations on the Tonto are mostly found in Mojave Sonoran Desert Scrub ecological response unit and potential habitat includes Interior Chaparral, Madrean Encinal Woodland, Pinyon-Juniper Evergreen Shrub, and Pinyon-Juniper Woodland ecological response units. Populations have been described as frequent to occassional at sites (SEINet 2016) (4). • Risk to populations on the Tonto appear low due to the range of potential habitat, locally abundant populations at sites, and no apparent threats (1). • Additionally there is a lack of scientific information on the ecology of the species (life history, etc.) and threats to determine species risk to persistence on the Tonto (6).	1,4,6
River hawthorn (*Crataegus rivularis*)	• Species is widespread with populations occurring throughout the northwest, Midwest and Arizona east to Texas (SEINet 2016) (3). • There are no mentioned threats (current and potential) to the species (1). • Information on population trends are unknown and species may be naturally uncommon (6).	1,3,6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Rusby's globemallow (*Sphaeralcea rusbyi*)	• Rusby's globemallow is regionally endemic (Arizona; southern; Utah, California, and Nevada). Both varieties (*S. rusbyi* var. *gilensis* and *S. rusbyi* var. *rusbyi*) are well distributed on the Tonto (3). • Globally, they are apparently secure (G4) but the state status has not yet been assessed or ranked (4). • More information (threats, population status) is needed to assess risk on the Tonto National Forest (6).	3,4,6
Senator Mine alumroot (*Heuchera eastwoodiae*)	• Senator Mine alumroot (*Heuchera eastwoodiae*) is a perennial herb endemic to central Arizona. On the Tonto, populations are scattered (present in all local zones) but locally common where found (SEINet 2016). Plants are not restricted to specific substrates or habitat features (that is, low habitat specificity); found at moist slopes in pine forests and canyons, rocky clay, crevices of basalt boulders and deep basaltic soils (3). • The effects of fire on the species is unknown but plants do occur in habitats where fires occur. Plants may be vulnerable to fires specifically among chaparral habitats (Interagency Sensitive Plant Assessment 2004). Current conditions on the Tonto show low departure in Interior Chaparral ecological response unit. While Interior Chaparral mostly experienced high-severity, stand-replacing fires at fire return intervals of 35 to more than 100 years, some areas did experience much shorter fire return intervals of 0 to 35 years. Currently, fire return intervals average 128 years in the ecological response unit. Therefore, while overall seral state departure is low, past fire suppression and exclusion has resulted in the build-up of dead fuel matter at some sites, capable of producing hot fires. Negative impacts are expected to be localized because current conditions show much smaller patch sizes (359 acres) from reference conditions (930-2,120 acres) (1). • While these delicate herbs may be sensitive to grazing pressure, the habitat is generally inaccessible (rocky slopes, crevices). For these reasons, there is currently no substantial concern for Senator Mine alumroot on the Tonto (2). • Surveys should be conducted to determine the extent of suitable habitat, impacts to species from fires, and other potential threats (6).	1,2,3,6
Showy maiden fern (*Thelypteris puberula*)	• Plants are found at the base of dry andesite cliffs in desert riparian areas (SEINet 2016) and along streams, seepage areas, and canyon settings (eFloras 2008) (4). • Two occurrences on the Tonto in Interior Chaparral and Mojave Sonoran Desert Scrub ecological response units. There is a lack of scientific information regarding the species status to determine substantial concern for the species persistence on the Tonto (6).	4,6
Sweet acacia (*Acacia farnesiana*)	• Species is widely distributed in tropical America and has spread by cultivation throughout many areas (3). • Species is globally secure (NatureServe 2016) (2). • Occurrences on the Tonto are documented as escaped cultivars (SEINet 2015) and locally abundant at sites. Many trees have naturalized along washes and streams at sandy-pebbly alluvium and desert scrub (4).	2,3,4

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Sweet cicely (*Osmorhiza brachypoda*)	• Naturally uncommon in Arizona, but widespread in California (SEINet 2015). Plants are noted as locally abundant at sites on the Tonto and represented accross a range of ecological response units including Mixed Conifer - Frequent Fire, Madrean Encinal Woodland, Interior Chaparral, Pinyon-Juniper Evergreen Shrub, Mojave Sonoran Desert Scrub, Juniper Grass, Ponderosa Pine - Evergreen Oak, and Semi-Desert Grassland (4). • There are no apparent threats to the species (AGFD 2005) (1).	1,4
Toumey agave (*Agave toumeyana* var. *toumeyana*)	• While *A. t.* var. *toumeyana* is endemic to central Arizona, plants are common where found (Hodgson et al. 2013) (2). • No sexual reproduction is taking place but like other agaves, plants can “turn on” asexual reproduction through vegetative means (W. Hodgson, personal communication, 2016) (1). • On the Tonto, populations are found at more than 25 locations at all local scales (3). • Plants are found at rocky limestone or basalt slopes and occupy a range of habitat types on the Tonto including Mojave Sonoran Desert Scrub, Interior Chaparral, Juniper Grass, Madrean Encinal Woodland, Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Woodland, and Semi-Desert Grassland ecological response units (4). • Information on population status and threats are unknown on the Tonto. Surveys on the Tonto is needed to determine threats and population status (6).	1,2,3,4,6
Toumey agave (*Agave toumeyana* var. *bella*)	• Populations are protected as salvage restricted under the Arizona Native Plant Law (regulated by the Arizona Department of Agriculture) to protect plants from damage and vandalism. *A. t.* var. *bella* was recommended endangered in 1978 but dropped in 1983 by the U.S. Fish and Wildlife Service because it was determined to be as common as *A. t.* var. *toumeyana* (Reichenbacher 1985) (1). • Additionally, the rugged mountain slopes in which plants are found minimize negative impacts to the species (NatureServe 2016) (2). • On the Tonto, populations are found at more than 20 locations at all local scales except the Lower Salt (3). • Plants are found at rocky limestone or basalt slopes and occupy a range of habitat types on the Tonto including Mojave Sonoran Desert Scrub, Interior Chaparral, Juniper Grass, Madrean Encinal Woodland, Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Woodland, and Semi-Desert Grassland ecological response units. Populations appear to be well distributed on the Tonto (4). • Surveys need to be conducted on the Tonto to determine if populations at sites are experiencing negative impacts from potential threats (collection and herbivory) (6).	1,2,3,4,6
Toumey groundsel (*Packera neomexicana* var*. toumeyi*)	• Populations relatively widespread in Arizona, with most occurrences in southeastern Arizona (SEINet 2015) (3). • Not restricted to specific habitat features (soils, substrate), locally common at sites and occupies a relatively wide range of habitat types (4). • Information on biology, habitat, and distribution studies are needed (AGFD 2004). There are no apparent threats to the species viability (6).	3,4,6

Common Name	Rationale for Removal from Potential Species of Conservation Concern List	Criteria for Removal
Mountain hollyfern (*Polystichum scopulinum*)	• Species is geographically widespread throughout western North America and Canada (NatureServe 2016) (3). • Habitat requirements and threats are unknown (NatureServe 2016) (6). • Species appears to be naturally restricted to montane habitats; however, the large geographic range of the species suggest a wide range of potential habitats (4).	3,4,6
Western mousetail (*Myosurus nitidus*)	• Species range extends from Santa Fe New Mexico through Colorado and Arizona. Most populations found at Kaibab Plateau in Arizona (3). • Information on population status and threats are unknown (NatureServe 2016, SEINet 2015) (6).	3,6
Western raspberry (*Rubus leucodermis*)	• Species is geographically widespread throughout western North America and Sonora Mexico (NatureServe 2016) (3). • Described as occasional to common where found (SEINet 2015) (4). • There are no apparent threats to the species viability (NatureServe 2016) (6).	3,4,6
Western shield fern (*Dryopteris arguta*)	• Species is wide spread from British Columbia, Canada and western U.S., to Baja California Mexico (NatureServe 2016, SEINet 2015) (3). • Information on population trends and threats are unknown (6).	3,6

In summary, table 113 lists the potential species of conservation concern documented to occur on the Tonto National Forest. For these scpecies, best available scientific information indicates substantial concern about their capability to persist over the long term in the plan area.

Table 113. Potential list of species of conservation concern for the Tonto National Forest

Common Name	Scientific Name	NatureServe rank
Birds		
American dipper	*Cinclus mexicanus*	G5 S3
Broad-billed hummingbird	*Cynathus latirostris*	G5 S3
Clark's grebe	*Aechmophorus clarkii*	G5 S3
Elf owl	*Micrathene whitneyi*	G5 S5
Gilded flicker	*Colaptes chrysoides*	G5 S5
Lewis's woodpecker	*Melanerpes lewis*	G4 S4
MacGillivray's warbler	*Geothlypis tolmiei*	G5 S2S3B,S4M
Olive-sided flycatcher	*Contopus cooperi*	G4 S2B
Desert purple martin	*Progne subis hesperia*	G5T4 S2S3B
Pacific wren	*Troglodytes pacificus*	G5 S1B,S2N
Red-faced warbler	*Cardellina rubrifrons*	G5 S4B
Sulphur-bellied flycatcher	*Myiodynastes luteiventris*	G5 S3
Western grebe	*Aechmophorus occidentalis*	G5 S3
Yellow-eyed junco	*Junco phaeonotus*	G5 S3
Mammals		
Allen's big-eared bat	*Idionycteris phyllotis*	G4 S2
California leaf-nosed bat	*Macrotus californicus*	G4 S3
Western red bat	*Lasiurus blossevilli*	G5, S3
Reptiles and Amphibians		
Lowland leopard frog	*Lithobates yavapaiensis*	G4 S3
Bezy's night lizard	*Xantusia bezyi*	G2 S2
Invertebrate		
Fossil springsnail	*Pyrgulopsis simplex*	G1G2 S1
Monarch butterfly	*Danaus plexippus pop. 1*	G4T2T3, SNRB
Phoenix talussnail	*Sonorella Allynsmithi*	G1 S1
Parker's cylloepus riffle beetle	*Cylloepus parkeri*	G1 S1
Fish		
Gila longfin dace	*Agosia chrysogaster chrysogaster**	G4T3G4 S3
Plants		
Alamos deer vetch	*Lotus alamosanus*	G3G4 S1
Aravaipa sage	*Salvia amissa*	G2 S2
Arizona bugbane	*Cimicifuga arizonica*	G2 S2
Arizona giant sedge	*Carex ultra*	G3 S2
Blumer's dock	*Rumex orthoneurus*	G3 S3
Broadleaf lupine	*Lupinus latifolius ssp. Leucanthus*	G5T1 S1
Davidson sage	*Salvia davidsonii*	G2? S2?

Common Name	Scientific Name	NatureServe rank
Fish Creek fleabane	*Erigeron piscaticus*	G1 S1
Fish Creek rock daisy	*Perityle saxicola*	G1 S1
Flagstaff Beardtongue	*Penstemon nudiflorus*	G2G3 S2S3
Gila rock daisy	*Perityle gilensis var. gilensis*	G2T2? S2
Grand Canyon century plant	*Agave phillipsiana*	G1 S1
Hodgson's fleabane	*Erigeron hodgsoniae*	Not Ranked
Hohokam agave	*Agave murpheyi*	G2 S2
Horseshoe deer vetch	*Lotus mearnsii var. equisolensis*	G3T1 S1
James' rubberweed	*Hymenoxys jamesii*	G2G3 S2S3
Mapleleaf false snapdragon	*Mabrya acerifolia*	G2 S2
Metcalfe's tick-trefoil	*Desmodium metcalfei*	G3G4 S2
Mt. Dellenbaugh sandwort	*Eremogone aberrans (Arenaria aberrans)*	G2 S2
Pinaleno Mountain rubberweed	*Hymenoxys ambigens var. ambigens*	G3?T1? S1?
Pringle's fleabane	*Erigeron pringlei*	G2 S2
Ripley wild buckwheat	*Eriogonum ripleyi*	G2 S2
Rusby's milkwort	*Polygala rusbyi*	G3 S3
Salt river rock daisy	*Perityle gilensis var. salensis*	G2?T2? S2
Sierra ancha fleabane	*Erigeron anchana*	G2 S2
Tonto basin agave	*Agave delamateri*	G2 S2
Verde breadroot	*Pediomelum verdiensis*	G1 S1

Step 3: Associate the federally listed and potential species of conservation concern with current ecological conditions and key ecosystem characteristics described within ecological response units for terrestrial species or within watersheds for aquatic species on each of the Tonto National Forest local zones.

The third step associated the federally listed species (table 110) and remaining potential species of conservation concern (table 112) with ecological response units as presented in the "Vegetation" section and key ecosystem characteristics described within ecological response units on the Tonto National Forest, at the local scale. Vegetation is one of the primary factors that influences species diversity and abundance and is one of the more obvious habitat components influenced by management, land use, and natural disturbance. In order to ensure the species risk assessment is relevant compared to other ecological risk assessments presented in this document and because vegetation is such a significant habitat component for species, vegetation types and key ecosystem characteristics were categorized following the ecological response units as applied in the "Terrestrial Ecosystems" and "Riparian Ecosystems" sections. These ecological response units are a stratification of ecosystem settings that are each similar in indicator plant species, succession patterns, and disturbance regimes that, in concept and resolution, are most useful to management. In other words, ecological response units are the range of plant associations (USDA Forest Service 1997), along with structure and process characteristics that would occur when natural disturbance regimes and biological processes prevail (Schussman and Smith 2006).

The ecological response unit framework represents all major ecosystem types of the region and a coarse stratification of biophysical themes. The ecological response units are map unit constructs;

that is, technical groupings of finer vegetation classes with similar site and disturbance history potential (Wahlberg et al. 2013).

For this reason, ecological response units do not necessarily reflect the vegetation currently present in a particular map unit but rather reflect the unit's site potential given the natural range of variation and historical disturbance regime. Ecological response units are described in much more detail in the Chapter 1, Vegetation.

Federally threatened and endangered species and potential species of conservation concern were associated with dominant ecological response unit types in table 114 and table 115. These associations were informed by a number of different sources including NatureServe Data Explorer (NatureServe 2014), the Southwest Environmental Information Network (SEINet), Heritage Data Management System abstracts, and personal communications with species experts and agency biologists.

In many cases, species' habitat needs were not represented solely by ecological response units (such as raptors requiring snags for perching or nesting, fish species with broad distributions varying by life stage, or snails requiring dense leaf litter to retain moisture). In these cases, special habitat features were recorded and assessed separately from the ecological response unit model. Overall, an effort was made to associate species with ecological response unit types whenever possible because later stages of forest plan revision and development will focus on the management of ecological response units.

Specific attention was given to aquatic- and riparian-dependent species with respect to their relationship with water resources found on the Tonto National Forest. We used watershed condition criteria for the seven subbasins (from the "Water Resources" section) across the five local zones to associate habitat conditions with the needs of these species.

These precise relationships are the premise of the coarse-filter approach discussed above and appropriate management of ecological response units and water resources are expected to benefit not only at-risk species but also those that are common and abundant. The relationship between species and special habitat features will help identify fine-filter plan components necessary for preserving species diversity on the Tonto National Forest.

Species can be grouped a number of different ways that are useful for identifying broad threats to their continued existence on the Tonto National Forest. For efficiency during the risk assessment portion of this evaluation, species were grouped according to their associated ecological response units, described above and presented in table 115. Grouping species in this manner will not accurately capture all of their specific habitat needs, so they have also been sorted by special habitat features (see previous pages). This information is summarized by taxonomic group below (note that species are typically associated with more than one ecological response unit; table 116). This paired well with the risk assessment process conducted on the ecological response unit types and presented in the "Vegetation" section.

Table 114. Federally listed threatened, endangered, and proposed species (or those with critical habitat) currently documented to occur in the plan area and associated ecological response unit (yes or no)

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	PJ Woodland	Juniper Grass	Madrean Encinal Woodland	PJ Evergreen Shrub	PJ Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Mammals																
Mexican gray wolf	no	no	no	no	no	no	no	no	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no
Lesser long-nosed bat	**yes**	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Ocelot	no	no	no	no	no	no	no	no	**yes**	no	no	no	no	no	no	no
Birds																
Mexican spotted owl	no	no	no	no	no	no	no	no	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no
Southwestern willow flycatcher	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Yellow-billed cuckoo	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Yuma Ridgeway's rail	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Amphibians																
Chiricahua leopard frog	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Fish																
Colorado pikeminnow	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Desert pupfish	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Gila chub	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Gila trout	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Gila topminnow	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Loach minnow	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	PJ Woodland	Juniper Grass	Madrean Encinal Woodland	PJ Evergreen Shrub	PJ Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Razorback sucker	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Spikedace	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Headwater chub	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Roundtail chub	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Reptiles																
Narrow-headed gartersnake	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Northern Mexican gartersnake	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Plants																
Arizona cliffrose	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Arizona hedgehog cactus	no	no	no	no	**yes**	**yes**	no	no	**yes**	no	no	no	no	no	no	no

* These ecological response units are provisional subclasses of Mojave Sonoran Desert Scrub.

Table 115. Potential species of conservation concern currently documented to occur in the plan area and associated ecological response unit (yes or no)

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	Pinyon-juniper Woodland	Juniper Grass	Madrean Encinal Woodland	Pinyon-juniper Evergreen Shrub	Pinyon-juniper Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Mammals																
Allen's big-eared bat	no	no	**yes**	no	no	no	**yes**	no	no	**yes**	no	**yes**	**yes**	no	**yes**	no
California leaf-nosed bat	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	**yes**	no
Western red bat	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Birds																
American dipper	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Broad-billed hummingbird	no	no	no	no	no	no	no	no	**yes**	no	no	no	no	no	**yes**	no
Clark's grebe	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Desert purple martin	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Elf owl	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	**yes**	no	no	**yes**	no
Gilded flicker	no	no	no	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Lewis's woodpecker	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**	no	no	no
MacGillivray's warbler	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Olive-sided flycatcher	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no	no
Pacific wren	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Red-faced warbler	no	no	no	no	no	no	no	no	no	no	no	**yes**	no	**yes**	**yes**	no

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	Pinyon-juniper Woodland	Juniper Grass	Madrean Encinal Woodland	Pinyon-juniper Evergreen Shrub	Pinyon-juniper Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Sulphur-bellied flycatcher	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Yellow-eyed junco	no	no	no	no	no	no	no	no	**yes**	no	no	no	no	**yes**	no	no
Western grebe	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Amphibians																
Lowland leopard frog	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Reptiles																
Bezy's night lizard	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no
Fish																
Gila longfin dace	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**
Invertebrate																
Fossil springsnail	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Monarch butterfly	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no
Phoenix talussnail	no	no	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Parker's cylloepus riffle beetle	no	no	no	no	no	no	no	no	no	no	no	no	no	no	**yes**	no
Plants																
Alamos deer vetch	no	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Aravaipa sage	no	no	no	no	**yes**	no	no	no	**yes**	**yes**	no	no	no	no	**yes**	no
Arizona bugbane	no	no	no	no	no	no	no	no	no	no	no	**yes**	no	**yes**	**yes**	no

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	Pinyon-juniper Woodland	Juniper Grass	Madrean Encinal Woodland	Pinyon-juniper Evergreen Shrub	Pinyon-juniper Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Arizona giant sedge	no	no	no	no	no	no	**yes**	no	no	no	no	no	no	no	**yes**	no
Blumer's dock	no	no	no	no	no	no	no	no	**yes**	no	no	**yes**	**yes**	**yes**	**yes**	no
Broadleaf lupine	no	no	no	no	**yes**	no	no	no	no	no	no	no	**yes**	**yes**	no	no
Davidson sage	no	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Fish Creek fleabane	no	no	no	**yes**	**yes**	no	no	no	no	no	no	no	no	no	**yes**	no
Fish Creek rock daisy	no	**yes**	**yes**	**yes**	no	no	no	no	no	**yes**	no	no	no	no	no	no
Flagstaff beardtongue	no	no	no	no	no	no	no	no	no	no	no	**yes**	**yes**	no	no	no
Gila rock daisy	no	**yes**	**yes**	**yes**	**yes**	no	no	**yes**	no	no	no	**yes**	no	no	no	no
Grand Canyon century plant	no	no	**yes**	no	no	no	no	**yes**	no	no	no	no	no	no	no	no
Hodgson's fleabane	no	no	no	no	**yes**	no	no	no	no	**yes**	no	**yes**	no	no	**yes**	no
Hohokam agave	no	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no
Horseshoe deer vetch	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Jame’s rubberweed	no	no	no	no	no	no	no	no	no	no	no	**yes**	no	no	no	no
Mapleleaf false snapdragon	no	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Metcalfe’s tick-trefoil	no	no	no	no	no	**yes**	no	no	no	no	**yes**	**yes**	**yes**	**yes**	no	no
Mt. Dellenbaugh sandwort	no	no	no	no	no	no	**yes**	no	no	no	no	**yes**	**yes**	no	no	no

Common Name	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	Pinyon-juniper Woodland	Juniper Grass	Madrean Encinal Woodland	Pinyon-juniper Evergreen Shrub	Pinyon-juniper Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Pinaleno mountain rubberweed	no	no	no	no	**yes**	no	**yes**	no	no	yes	no	no	no	no	no	no
Pringle's fleabane	no	no	no	no	**yes**	no	**yes**	**yes**	no	**yes**	no	**yes**	no	no	no	no
Ripley wild buckwheat	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Rusby's milkwort	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no
Salt River rock daisy	no	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	no	no	no	no	no	no	no	no
Sierra Ancha fleabane	no	no	no	no	**yes**	no	no	no	no	**yes**	no	**yes**	no	no	**yes**	no
Tonto Basin agave	no	**yes**	**yes**	**yes**	**yes**	no	no	**yes**	no	no	no	no	no	no	no	no
Verde breadroot	no	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	no	no

* These ecological response units are provisional subclasses of Mojave Sonoran Desert Scrub.

Table 116. Number of federally listed and potential species of conservation concern and their associated ecological response units

Species Type	Sonora-Mohave Mixed Salt Desert Scrub	Sonora-Mojave Creosote-Bursage Desert Scrub*	Sonoran Mid-Elevation Desert Scrub*	Sonoran Paloverde-Mixed Cactus Desert Scrub*	Interior Chaparral	Semi-Desert Grassland	Pinyon-juniper Woodland	Juniper Grass	Madrean Encinal Woodland	Pinyon-juniper Evergreen Shrub	Pinyon-juniper Grass	Ponderosa Pine - Evergreen Oak	Ponderosa Pine Forest	Mixed Conifer - Frequent Fire	Riparian	Water
Mammals	2	1	2	1	0	0	1	0	1	2	1	2	2	1	4	0
Birds	1	1	2	2	0	0	0	0	2	1	1	4	2	4	14	0
Amphibians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Reptiles	1	1	1	1	1	0	0	0	0	0	0	0	0	0	2	0
Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11
Invertebrate	1	1	2	2	1	1	1	1	1	1	1	2	2	2	4	0
Plants	4	13	14	14	12	3	4	5	3	6	1	10	5	4	7	0
Total	**9**	**17**	**21**	**20**	**14**	**4**	**6**	**6**	**7**	**10**	**4**	**18**	**11**	**11**	**44**	**12**

* These ecological response units are provisional subclasses of Mojave Sonoran Desert Scrub.

Federally listed (*) and potential species of conservation concern known to currently occur in the plan area and associated special habitat features are as follows:

Tree Features (cavities, snags, leaves, bark, downed logs, leaf or forest litter)

- Mexican spotted owl*
- Western red bat
- Desert purple martin
- Pacific wren
- Olive-sided flycatcher
- Sulphur-bellied flycatcher
- Yellow-eyed junco
- Lewis's woodpecker

Rock Features (canyons, cliffs, crevices, outcrops, talus slopes)

- Mexican spotted owl*
- American dipper
- Bezy's night lizard
- Phoenix talussnail
- Mapleleaf false snapdragon
- Salt River rock daisy
- Gila rock daisy
- Fish Creek rock daisy
- Hodgson's fleabane
- Pringle's fleabane
- Arizona hedgehog cactus*
- Arizona cliffrose*
- Davidson sage

Aquatic Features (riparian areas, springs, and permanent water)

- Mexican spotted owl*
- Southwestern willow flycatcher*
- Yellow-billed cuckoo*
- Yuma ridgeway's rail*
- Chiricahua leopard frog*
- Narrow-headed gartersnake*
- Northern Mexican gartersnake*
- MacGillivray's warbler
- Pacific wren
- Red-faced warbler
- Sulphur-bellied flycatcher
- American dipper
- Western grebe
- Clark's grebe
- Broad-billed hummingbird
- Fossil springsnail
- Parker's cyllopeus riffle beetle
- Gila trout*
- Gila chub*
- Gila longfin dace
- Gila topminnow*
- Desert pupfish*
- Razorback sucker*
- Colorado pikeminnow*
- Headwater chub*
- Roundtail chub*
- Loach minnow*
- Spikedace*
- Grand Canyon century plant
- Broadleaf lupine
- Arizona giant sedge
- Blumer's dock
- Aravaipa sage
- Fish Creek fleabane
- Alamos deer vetch
- Monarch butterfly

Meadows and Small Openings

- Lewis's woodpecker
- Olive-sided flycatcher
- Alamos deer vetch

Soil Features (soil type, soil permeability, and soil condition)

- Phoenix talussnail
- Fish Creek fleabane
- Verde breadroot
- Ripley wild buckwheat
- Horseshoe deer vetch
- Aravaipa sage
- Arizona cliffrose*
- Davidson Sage
- Rusby's milkwort

Table 117. Federally listed and potential species of conservation concern associated with each local zone that include all ecological response units. Note some species are associated with more than one local zone

Species Type	1: Agua Fria	2: Lower Verde	3: Tonto Basin	4: Upper Salt	5: Lower Salt
Mammals	6*	6*	6*	6*	6*
Birds	4*	14*	15*	13*	9*
Amphibians	0	2*	2*	1*	1
Reptiles	2	4*	3*	2*	2
Fish	3*	9*	6*	3*	3*
Invertebrate	0	2	0	0	1
Plants	2	11*	8	13*	6*
Total	17	48	40	38	28

* Denotes one or more federally listed species is included.

Note: The local scale is not as likely to drive ecological need for change but may drive development of plan components. The local scale of analysis consists of fourth-level watersheds. Watersheds that contained less than 10% on the Tonto were incorporated into an adjoining 4th-level watershed.

Step 4: Perform a risk analysis on federally listed and potential species of conservation concern with their associated habitats.

The dual coarse-filter and fine-filter approach described above was used to assess risk to species on the Tonto National Forest. The coarse-filter approach considered habitat (ecological response units) associated with species, and current condition and future trends modeled using the Vegetation Dynamics Development Tool (VDDT 2006). This tool was used to simulate stand structure 15,100, and 1,000 years into the future under current management (modeled at the plan scale). Departure from reference conditions for current conditions are displayed for local and zone plan and context scales in table 118 along with projections for seral state departure (analyzed at the plan scale) at 100 years. Departure is based on a nominal classification: low 0 to 33 percent (green cells); moderate 34 to 66 percent (yellow cells); high 66 to 100 percent (red cells). For further information, reference the "Terrestrial Ecosystems" section.

Sometimes portions or all of a given ecosystem characteristic may be altered so that recovery is not possible even if threats are controlled or reduced (such as loss of topsoil from recent large fires). In some cases, the response from the reduction of the threat may be so slow that current departures would essentially be present for hundreds of years (for example, restoring fire in spruce-fir forest when the historical fire return interval is several hundred years).

Fish and other aquatic species were assessed using distribution and watershed condition criteria for the seven subbasins (from the "Water Resources" section) across the five local zones (from the "Vegetation" section) by merging the condition information from the Middle Gila subbasin into the Lower Salt and the San Carlos subbasin into the Upper Salt. Most of these species are found in watersheds in more than one zone, but some species are spring or pond endemics found only found in one spring complex. Native aquatic species have adapted to the historic range of variation in the hydrologic regime and in water quality conditions. Species have developed specified life histories and physical and physiological adaptations to best survive the conditions they encounter in their environment. Therefore, changes in the hydrologic regime and water quality (pH, dissolved oxygen, contaminants, nutrients, turbidity, and temperature) in springs and streams outside the historic range of variation can lead to increased physiological stress, susceptibility to disease, and morbidity (Rinne and Miller 2006). This anaylsis assumed watersheds with normal hydrologic function that are devoid of nonnative predatory or competitive species are most likely to produce habitat for native species. Watershed subbasin departure was ranked as low, moderate, or high based on the percent departure from historic conditions. Additionally, the number of stream miles occupied by native fish only was calculated in each watershed subbasin (see Chapter 6, section “Aquatic Biota”). These metrics were used in estimating ecological conditions for aquatic species and assessing species level risks.

Trend was not calculated for ecological response units where Tonto National Forest acreages were too small to adequately model in VDDT and shrubland types. This included the ecological response units associated with at-risk species in this analysis. Nearly all of the ecological response units modeled are currently departed from reference and are predicted to be departed from reference 100 years from now. An extensive discussion of that analysis is presented in the “Vegetation” section and only briefly summarized here. Fire regimes are disrupted in nearly half of the ecological response units present on the Tonto, typically from historical fire suppression activities. Fire suppression has led to an overall change in seral stage proportion in most of the woody ecological response units modeled in VDDT, and many stands are currently characterized by smaller diameter trees with a denser distribution. Reference conditions in these stands were characterized by more widely spaced trees of medium or larger diameters. Many wildlife species are dependent on shrub and forbs species that once grew in the understory of various ecological response units but, in many cases, are now crowded out by the shift in seral structure and density. Additionally, years of prolonged drought, combined with overstocked stands, increases the risk of higher-intensity, more severe fires that could further permanently change habitat.

Table 118. Current seral state departure for each ecological response unit (ERU) at the three different analysis scales (local/zone, plan, and context)

System Type	ERU code	ERU name	Departure (percent)[1]							
			Current conditions							100-year Projection
			Context Landscape	Plan Scale (Tonto NF)	Local/zone scale[2]					
					1:Agua Fria	2: Lower Verde	3: Tonto Basin	4: Upper Salt	5: Lower Salt	
Shrubland	SDS[3]	Sonora-Mohave Mixed Salt Desert Scrub		7						NA
Shrubland	MSDS (CB)[4]	Sonora-Mojave Creosote-Bursage Desert Scrub[3]	0	1	5	3		5	1	NA
Shrubland	MSDS (SOS)[4]	Sonoran Mid-Elevation Desert Scrub	53	52	53	46	58	40	57	NA
Shrubland	MSDS (SP)	Sonoran Paloverde-Mixed Cactus Desert Scrub	9	9	12	7	5	5	15	71
Shrubland	IC	Interior Chaparral	10	30	40	31	41	11	42	5
Grassland	SDG	Semi-Desert Grassland	78	94	91	93	94	95	95	95
Woodland	PJO	Pinyon-Juniper Woodland	23	30	**59***	36	29	14		31
Woodland	JUG	Juniper Grass	56	65	64	65	67	65	**88***	32
Woodland	MEW	Madrean Encinal Woodland	40	43		44	42	48	**43***	50
Woodland	PJC	Pinyon-Juniper Evergreen Shrub	54	76	86	75	72	77	84	49
Woodland	PJG	Pinyon-Juniper Grass	42	35	**35***	38	35	40		27
Forest	PPE	Ponderosa Pine - Evergreen Oak	71	73		68	74	79	**56***	39
Forest	PPF	Ponderosa Pine Forest	95	95			97	94		91
Forest	MCD	Mixed Conifer - Frequent Fire	73	62		54	75	**42***		62

[1] Departure is a nominal classification: low (0 to 33 percent), green; moderate (34 to 66 percent) yellow; high (66 to 100 percent), red.

[2] At the local/zone scale, numbers in boldface type and an * mean the ecological response unit is less than 1 percent of local scale. Blank cells mean the ecological response unit is not present or sufficiently distributed at scale for analysis.

[3] Data is not available at the context scale, and there are insufficient acres on the Tonto National Forest to model departure (100-year projection at plan scale).

[4] Models are currently unavailable for these provisional subclasses.

Other features important to wildlife and plants are also departed from reference conditions. Examples are such as coarse woody material (for example, downed logs) that provide shelter, food, and moisture retention and standing snags of sufficient size for roosting, nesting, or foraging. See the section on “Coarse Woody Debris and Snag Density” on page 30, for more information. These features are more transient on the landscape. As snags fall and decay, standing live trees die becoming new snags. If the seral stage proportions of most ecological response units trend toward smaller diameter trees, future trees may not be large enough to provide the habitat required by species such as Mexican spotted owl.

A number of assumptions were used in determining the risk and overall status of species in the plan area:

1. The **extent of habitat available** to a species does not change from reference to current to future conditions. As stated above, ecological response unit map units reflect the potential of a site and the historical disturbance regime. These are not expected to change at the time scales used. Therefore, the amount of habitat available in historical and reference conditions does not change as one moves to current or future trend. Ecological response units making up less than 5 percent of the total area of all five zones are considered as providing low amounts of habitat. Moderate amounts of habitat are those ecological response units that range from 6 to 50 percent, and high amounts of habitat make up 51 to 100 percent of the area. There are no ecological response units that make up more than 50 percent of the total plan area.

2. **Quality of habitat represents** ecological response unit departure from reference. It is assumed that during reference conditions, all habitats were sufficient to maintain viability. Current conditions of habitats in ecological response units in low departure (0 to 33 percent departure from reference condition) are considered high quality; ecological response units in moderate departure (34 to 66 percent departure from reference condition) are moderate quality; and ecological response units in high departure (67 to 100 percent departure from reference condition) are low quality. The future trend in quality of habitat reflects ecological response units modeled for 100 years from now. While we acknowledge that ecological response units that are highly departed from reference are not necessarily low quality habitat for wildlife, it was an assumption of this assessment. The VDDT modeling for ecological response units on the Tonto National Forest represents the most comprehensive habitat data available; however, where more detailed habitat information was available for species of conservation concern, it was noted.

3. **Distribution** (in the planning unit) was measured based on known occurrences and distribution or habitat. Habitat was determined to be either even (habitat dispersed broadly), restricted (habitat restricted to certain areas) or highly fragmented (habitat isolated and separated by distance or barriers). As in number 1 above, these ratings were assessed to be consistent across historical, current, and future trends.

4. **Size** refers to the overall population size across the species’ range. Detailed information about populations of each species on just the Tonto National Forest was not available in most cases. Population sizes were categorized as small, moderate, or large.

5. **Stability** refers to a population’s relative trend toward increasing, decreasing, or remaining the same. In nearly all cases, population trend data specific to the Tonto National Forest were not available or were dated; this constitutes a gap in the analysis. For these instances, trend was inferred from regional or state information where possible. If it was not clear if populations were declining or increasing or if breeding bird survey data did not indicate

significant trends, populations were assumed to be stable. All species were ranked as either in decline, stable, or gaining.

Other stressors or other threats to species including harassment by humans, invasive species, diseases, parasitism, obstructions (collisions with wind turbines, cars, highways), or predation are listed below (* denotes federally listed species, all others are potential species of conservation concern.)

Harassment (disrupting species during sensitive life stages, human presence, indiscriminate shooting, dogs, disturbance from mining activities, picking/digging plants)

- Mexican spotted owl*
- Allen’s big-eared bat
- California leaf-nosed bat
- Western red bat
- Arizona hedgehog cactus* (*Echinocereus triglochidiatus* var. *arizonicus*)
- Gilded flicker
- Broadleaf lupine (*Lupinus latifolius* ssp. *leucanthus*)
- Gila rock daisy (*Perityle gilensis* var. *gilensis*)
- Mapleleaf false snapdragon (*Mabrya acerifolia*)
- Ripley’s buckwheat (*Eriogonum ripleyi*)
- Hohokam agave (*Agave murpheyi*)

Invasive Species and Introduced Species Competition (such as bullfrogs, European starling, tamarisk, Russian olive, etc.)

- Chiricahua leopard frog*
- Lowland leopard frog
- Southwestern willow flycatcher*
- Gila topminnow*
- Gila chub*
- Gila trout*
- Gila longfin dace
- Desert pupfish*
- Spikedace*
- Loach minnow*
- Razorback sucker*
- Colorado pikeminnow*
- Headwater chub*
- Roundtail chub*
- American dipper
- Desert purple martin

Diseases (chytrid fungus, sylvatic plague, whirling disease, West Nile virus)

- Chiricahua leopard frog*
- Lowland leopard frog
- Gila trout*
- Tonto Basin agave (*Agave delamateri)*

Obstruction (collisions with wind turbines, towers, or vehicles)

- Rusby’s milkwort (*Polygala rusbyi*)
- Ripley’s buckwheat (*Eriogonum ripleyi*)
- Horseshoe deer vetch (*Lotus mearnsii* var. *equisolensis*)

Predation (predation from nonnative invasive species, crayfish, bullfrog)

- Chiricahua leopard frog*
- Narrow-headed gartersnake*
- Northern Mexican gartersnake*
- Lowland leopard frog
- Colorado pikeminnow*
- Desert pupfish*
- Gila chub*
- Gila topminnow*
- Gila trout*
- Gila longfin dace
- Loach minnow*
- Razorback sucker*
- Spikedace*
- Headwater chub*
- Roundtail chub*

Competition from introduced species (bullfrog, catfish, mosquitofish, nonnative rainbow trout)

- Chiricahua leopard frog*
- Narrow-headed gartersnake*
- Northern Mexican gartersnake*
- Lowland leopard frog
- Desert pupfish*
- Colorado pikeminnow*
- Gila chub*
- Gila topminnow*
- Gila trout*
- Gila longfin dace
- Loach minnow*
- Razorback sucker*
- Spikedace*
- Headwater chub*
- Roundtail chub*

Federally Listed Species, Species of Conservation Concern, and Current Tonto National Forest Management Direction

All of the federally listed species and potential species of conservation concern may be affected by current forest plan-authorized management activities on the Tonto National Forest, especially those which pertain to timber management, watershed protection and improvement, and wildlife management. Here we describe each species, its distribution on the Tonto, and relative risk based on the ecological response unit and zone overlap information presented in table 118 on page 369, as well as additional risk information presented above. Risk was not assessed for ecological response units or other habitat factors outside Tonto National Forest-managed lands. Therefore, it is not possible to state with certainty the overall risk to the species at the context scale. However, for some of these species, habitat provided on the Tonto represents the majority of the habitat or, in some cases, the only habitat available. Changing land use patterns, habitat degradation and loss, or simply the lack of suitable habitat outside the Tonto National Forest place a particular emphasis on the Tonto National Forest to maintain these species.

Federally Listed Species

Amphibians

Chiricahua leopard frog (*Lithobates chiricahuensis*) is a federally threatened species and is currently known to occur only on the Payson and Pleasant Valley Ranger Districts. Since 1998, they have been detected in and released at over 30 sites in creeks, springs, and stocktanks in both management areas. In this document, potential habitat for the species is defined as all sites where Chiricahua leopard frogs have been detected or released since 1998 plus a 1-mile buffer to account for overland dispersal. This results in approximately 42,274 acres of potential Chiricahua leopard frog habitat on the Tonto National Forest.

This species can be found at elevations between 3,281 and 8,890 feet (U.S. Fish and Wildlife Service 2007). Habitat includes montane and river valley cienegas, springs, pools, cattle tanks, lakes, reservoirs, beaver ponds, streams, and rivers. Breeding habitat requires sufficient water for adult survival and a minimum larval period of three months; however, they are excluded from many perennial waters by nonnative predators and competitors (U.S. Fish and Wildlife Service 2007). Chiricahua leopard frogs depend on a narrow range of aquatic habitats that lie between truly ephemeral and perennial habitats (U.S. Fish and Wildlife Service 2007). In the absence of introduced predators or competitors, they are opportunistic and frequently inhabit man-made habitats. Additional habitat characteristics include both shallow and deeper waters, undercut banks for refugia, a substrate other than just rock, basking sites, and varying vegetation (U.S. Fish and Wildlife Service 2007).

Critical habitat has been designated on the Upper Salt and Lower Verde local zones; habitat is also available in the Tonto zone. The Chiricahua leopard frog is associated with higher elevation ecological response units: Fremont Cottonwood – Conifer, Cottonwood Group, and Ponderosa Pine/Willow. Currently, these ecological response units are largely functioning at high risk. Throughout the planning area, 31 percent of riparian areas are classified as unstable, while an additional 51 percent are considered impaired. Only 18 percent of streams assessed were considered stable.

The largest threats to Chiricahua leopard frogs include predation by nonnative predators, such as American bullfrogs, fish, crayfish, and barred tiger salamanders and the introduced fungal disease, chytridiomycosis. Habitat degradation is also an issue and has resulted from various activities including water diversion, groundwater pumping, contamination, grazing, altered fire regimes, mining, livestock management, and grazing. The Tonto National Forest is responsible for managing grazing, recreation, and groundwater pumping that can affect leopard frog habitat. However, riparian systems are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas. Additionally, the natural metapopulation dynamics of frog populations may have become disrupted under altered ecological conditions. This puts the remaining, fragmented populations potentially at risk of chance events (U.S. Fish and Wildlife Service 2007).

While there has been active work to contribute to the recovery of the Chiricahua leopard frog, the cumulative loss of habitat and the natural dynamics of aquatic systems in the Southwest suggest a long-term risk of persistence for this species in the planning area.

Birds

Mexican spotted owl (*Strix occidentalis lucida*) is currently distributed on the Payson/Pleasant Valley, Globe, Tonto Basin, and Mesa Ranger Districts of the Tonto National Forest. The Tonto contains 448,000 acres of designated critical habitat. Protected activity centers and unoccupied mixed conifer and pine-oak are considered recovery habitat.

Spotted owls require mature, old-growth forests with complex, uneven-aged stands that are multi-storied. Additional habitat characteristics include proximity to riparian areas, a variety of standing large snags for roosting and nesting, and cavities in vertical canyon walls (U.S. Fish and Wildlife Service 2013). They occur in a variety of habitats, including Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Grass, Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, Mixed Conifer - Frequent Fire, and Riparian ecological response units. All ecological response units used by the Mexican spotted owl are moderately to highly departed from reference conditions. This is due largely to past policies of fire exclusion, selective logging, and intensive grazing in fire adapted forests.

Currently, theses habitats have trended towards higher stand densities and altered species compositions that favor more shade-tolerant, less fire-resistant species. While Pinyon-Juniper Evergreen Shrub and Pinyon-Juniper Grass ecological response units are expected to move more towards reference conditions in the future, Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, and Mixed Conifer - Frequent Fire ecological response units are projected to continue to infill with understory trees, trending away from reference conditions. With a continued lack of frequent, low-intensity fire, these systems will be a greater risk of tree mortality from uncharacteristic fire, insects, and disease, further reducing available owl habitat.

Timber harvest, prescribed burning, and other management activities that occur in the planning area are designed following the Mexican spotted owl recovery plan (2012) along with consultation with the U.S. Fish and Wildlife Service; however, management and recreational activities may still impact owls and their habitat.

The status of the Mexican spotted owl was last reviewed by the U.S. Fish and Wildlife Service in 2013. The species continues to be classified as threatened due to the threat of high-severity, stand-replacing fire and forest management; however, the owl is not in immediate danger of extinction (U.S. Fish and Wildlife Service 2013).

Southwestern willow flycatcher (*Empidonax traillii extimus*): There are approximately 12,380 acres of designated critical habitat for southwestern willow flycatcher (flycatcher) on the Tonto National Forest, all of which are located in the Gila recovery unit. Critical habitat can be found on the Cave Creek, Globe, Payson, and Tonto Basin Ranger Districts and includes portions of two management units: approximately 9,250 acres in the Roosevelt management unit and approximately 3,310 acres in Verde management unit. The majority of flycatcher habitat and the second largest known population occurs around the Theodore Roosevelt Lake area on the Tonto Ranger District.

The flycatcher requires riparian habitat along a dynamic river or lakeside, in a natural or manmade successional environment (for nesting, foraging, migration, dispersal, and shelter) comprised of trees and shrubs (for example, Gooding’s willow, coyote willow, Geyer’s willow, arroyo willow, red willow, yewleaf willow, pacific willow, boxelder, tamarisk, Russian olive, buttonbush, cottonwood, stinging nettle, alder, velvet ash, poison hemlock, blackberry, seep willow, oak, rose, sycamore, false indigo, Pacific poison ivy, grape, Virginia creeper, Siberian elm, and walnut).

Habitat for this species likely spans four local zones in the planning area: Upper Salt, Tonto Basin, Lower Verde, and Lower Salt. The flycatcher may occur in several riparian ecological response units, including Fremont Cottonwood – Conifer, Cottonwood Group, Ponderosa Pine/Willow. Throughout the planning area, 31 percent of riparian areas are classified as unstable while an additional 51 percent are considered impaired. Only 18 percent of streams assessed were considered stable.

Habitat loss and modification is considered a key risk to the southwestern willow flycatcher. Such loss of habitat has occurred due to various factors, including dams and reservoirs, diversions and groundwater pumping, vegetation control, livestock grazing, recreation, fire, agricultural development, and urbanization (U.S. Fish and Wildlife Service 2002). The introduction of tamarisk also creates some issues for the flycatcher. Tamarisk is frequently used as breeding habitat; however, it may facilitate more frequent fire. Additionally, a number of efforts are ongoing to remove tamarisk from riparian areas. Parasitism, small populations, and stresses in migration and winter ranges are also risks to flycatcher populations. The Tonto National Forest manages grazing, recreation, and groundwater pumping that can affect riparian areas. However, riparian systems are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas (U.S. Fish and Wildlife Service 2002).

While there are a number risk factors, habitat loss and modification in riparian areas are key. In 2014, the U.S. Fish and Wildlife Service conducted a 5-year review on the status of the southwestern flycatcher and concluded no change was needed in the status of the species (U.S.

Fish and Wildlife Service 2014). The flycatcher continues to be listed as a federally endangered species.

Yellow-billed cuckoo (*Coccyzus americanus occidentalis*) is a federally threatened species with approximately 9,714 acres of proposed critical habitat on the Tonto National Forest. Critical habitat can be found on the Cave Creek, Globe, and Tonto Basin Ranger Districts.

Yellow-billed cuckoos require dynamic river systems with hydrologic processes that encourage sediment movement and deposits that allow seedling germination and promote plant growth, maintenance, health, and vigor (such as lower-gradient streams and broad floodplains, elevated subsurface groundwater table, and perennial rivers and streams). This allows habitat to regenerate at regular intervals, leading to riparian vegetation with variously aged patches from young to old.

The yellow-billed cuckoo is most likely to occur throughout riparian ecological response units. Throughout the planning area, 31 percent of riparian areas are classified as unstable while an additional 51 percent are considered impaired. Only 18 percent of streams assessed were considered stable. The greatest threat to the species has been reported to be loss of this riparian habitat. It has been estimated that 90 percent of the cuckoo's streamside habitat has been lost. Habitat loss in the West is attributed to agriculture, dams, river flow management, overgrazing (unmanaged cattle grazing that contributes to the loss of subcanopy vegetation and cottonwood regeneration), and competition from exotic plants such as tamarisk. As long-distance migrants, cuckoos are also vulnerable to collisions with tall, man-made structures including towers, antennas, and wind turbines (Laymon 1998).

While the Tonto National Forest manages grazing, recreation, and groundwater pumping that can affect riparian areas; riparian systems are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas. Ultimately, recovery of the cuckoo in the planning area likely depends on the recovery of riparian habitat on the Tonto.

Yuma Ridgeway's rail (*Rallus obsoletus yumanensis*): The Tonto National Forest lies at the extreme eastern portion of the range occupied by the federally endangered Yuma Ridgeway's rail. In conjunction with the U.S. Fish and Wildlife Service and former Tonto National Forest biologist Amyann Madara-Yagla, Tonto National Forest GIS data was refined in April 2015 to identify potential habitat. Potential habitat is limited to approximately 40.53 acres of cattail habitat on Roosevelt Lake and areas immediately adjacent on the Salt River and Tonto Creek. Formal Yuma Ridgeway's rail surveys have been conducted on the Tonto as part of the Salt River project under the Roosevelt Lake Conservation Program. These surveys are conducted when conditions are conducive to providing a minimum of 3 acres of potential habitat at the confluence of the Tonto Creek and Roosevelt Lake. Two Yuma Ridgeway's rails were detected in 2002, and a lone bird was detected in 2004. Since 2004, the Salt River project has not conducted surveys due to reservoir fluctuations and the lack of the 3-acre minimum habitat requirement.

The Yuma Ridgeway's rail requires freshwater marshes with cattail and bulrush, mixed with various riparian trees and shrubs. They are found in areas with varying vegetation height and open water in the form of pools or channels. Open dry ground between consistent water levels are also important characteristics. These are naturally successional systems that degrade in habitat quality over time without disturbance (U.S. Fish and Wildlife Service 2009).

In our assessment of riparian conditions at the local scale Tonto Basin, 37 percent of riparian areas were classified as unstable, 49 percent as impaired, and 14 percent as stable. Small and large dams, channelization, bank stabilization, levee construction, and control of water flows to streams and rivers have disrupted the natural hydrologic cycles that create and destroy marshes and floodplains used by the Yuma Ridgeway's rail (U.S. Fish and Wildlife Service 2009). At present, available habitat is largely man-made as part of effluent-supported marshes or habitat created by dams and diversions (U.S. Fish and Wildlife Service 2009).

Riparian systems are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas. Full restoration of the hydrologic cycles that provide habitat for the rail is not likely to occur; thus, future habitat depends on human management of marsh wetlands (U.S. Fish and Wildlife Service 2009). Climate change may also play a role in the future condition of rail habitat if warming results in water shortages, and shrinking available wetlands (U.S. Fish and Wildlife Service 2009).

The Tonto National Forest manages grazing, recreation, and groundwater pumping that can affect riparian areas; however, recreational activities also have the potential to affect rails in some areas. Noise from vehicles and people, recreational facilities, risk of fire, and predation from pets are considered potential risks in rail habitat (U.S. Fish and Wildlife Service 2009). Additionally, because the Yuma Ridgeway's rail exists in three core habits, reproductive isolation may be an issue; however, the extent to which migration or dispersal occurs between these areas is unclear (U.S. Fish and Wildlife Service 2009).

Due to the loss of habitat and ecological process that provide its habitat, the Yuma Ridgeway's rail is listed as endangered throughout its range.

Fish

Colorado pikeminnow (*Ptychocheilus lucius*) is endemic to the Colorado River watersheds in Wyoming, Utah, Colorado, Arizona, and California; however, populations have been extirpated from Arizona and reintroduced under "experimental, non-essential" status of section 10J of the Endangered Species Act (AGFD 2002a, U.S. Fish and Wildlife Service 1985, 1994). NatureServe's rounded global status for Colorado pikeminnow is G1 (critically imperiled) and state status in Arizona as S1 (critically imperiled) due to its small reduced abundance and distribution, and the presence of dams which prevent spawning migration and egg incubation (NatureServe 2015). The species is presently listed as Tier 1A species of greatest conservation need for the State of Arizona (AGFD 2012). Critical habitat is not designated for the experimental non-essential status population segments found on the Tonto National Forest (U.S. Fish and Wildlife Service 1994).

This species of fish is adapted to large central and southwestern North American river and perennial stream habitats, including deep pools, eddies, variable temperatures, stochastic flows, and corresponding turbidity. Colorado pikeminnow populations have been reintroduced at larger perennial streams and rivers in the Upper Salt, Lower Salt, Lower Verde, and the Tonto Basin local zones (Haigler Creeks).

Colorado pikeminnow populations have been extirpated or are declining across the Tonto due to competition and predation by nonnative fish and crayfish species, pesticides, and pollutants (AGFD 2002a). Much of its habitat lies within large river systems that have been developed with numerous impoundments that alter stream environments and are also managed for introduced sportfish species which prey on juveniles and eggs (AGFD 2002a, U.S. Fish and Wildlife Service 1994). Threats include development within and outside the Tonto National Forest boundary that result in groundwater depletion thus leading to reductions in stream flow and changes in water quality, in combination with climate change impacts. These aspects, though discussed in the assessment, are difficult to quantify and result in declines in habitat availability and quality. Additionally, management of nonnative fish species within waterways on the Tonto is conducted by Arizona Game and Fish Department. These fisheries have adverse effects to native fish populations from predation, competition, and potential disease transmission.

Risk for continued habitat loss for this species likely will remain high due to moderate to high departure from reference conditions in nearly all of its habitat on the Tonto National Forst and high departure from reference for nonnative species. Watershed condition is moderate to highly departed where this species is found on the Tonto: Upper Salt (97.8 percent of 6th-level hydrologic unit code subwatersheds are functioning at risk or impaired); Lower Salt (75 percent of 6th-level hydrologic unit code are functioning at risk or impaired); Lower Verde (67.5 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Tonto Basin (83.7 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired). Additionally, all four watersheds are considered highly departed from reference for perennial stream miles containing nonnative species. Tonto National Forest actions that can affect pikeminnow include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, stream diversion, and permitted livestock grazing. Management needs include re-establishment of adult or large juvenile pikeminnow in historical habitats, amelioration of impacts from nonnative predatory and competitor fish species, and maintenance and restoration of select habitats within historical range

Desert pupfish (*Cyprinodon macularius*) were listed as endangered in 1986 under the Endangered Species Act (U.S. Fish and Wildlife Service 1986). Desert pupfish were extinct from Arizona but have been reestablished through conservation programs with Arizona Game and Fish Department and the U.S. Fish and Wildlife Service (AGFD 2001a). NatureServe's rounded global status for desert pupfish is G1 (critically imperiled) and state status in Arizona as S1 (critically imperiled) due to its low abundance and distribution, loss of native habitat, and threats from introduced species (NatureServe 2015). The species is presently listed as Tier 1A species of greatest conservation need for the State of Arizona (AGFD 2012). No critical habitat has been designated for this species.

Reestablished populations exist along the Gila, Lower Salt, and Agua Fria River drainages in Lower Salt and Agua Fria zones that include Cave Creek, Globe, and Mesa Ranger Districts of the Tonto National Forest (AGFD 2001a).

Desert pupfish are a warmwater fish species that occupy shallow perennial springs, cienegas, small streams, and marshes. This species is often associated with areas of soft substrates and clear water. Despite numerous conservation efforts, desert pupfish may be down-listed, but due to changes in the hydrologic regime that has fragmented or damaged suitable habitats and threats from introduced species, this fish species will likely not be delisted in the foreseeable future.

Risk for continued habitat loss for this species likely will remain high due to competition with introduced species and increasing pressures for use of surface waters. Watershed condition is moderate to highly departed where this species is found on the Tonto: Upper Salt (97.8 percent of 6th-level hydrologic unit code subwatersheds are functioning at risk or impaired); Lower Salt (75 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Middle Gila (100 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Agua Fria (100 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired). All four watersheds are considered highly departed from reference for perennial stream miles containing nonnative species.

Gila chub (*Gila intermedia*) were listed as endangered in 2005 under the Endangered Species Act (U.S. Fish and Wildlife Service 2005). The taxonomic uniqueness of the three chub species currently federally listed or proposed for listing in the State of Arizona (gila, roundtail, and headwater chub) is under review by the U.S. Fish and Wildlife Service and the date for final decisions have been extended (U.S. Fish and Wildlife Service 2016). The final decision, when issued, could substantially change the assessment results for these three species. Forest Service policy states that determinations be made based on the current status of the species as listed at the time of publication of forest documents, and we acknowledge that this may substantially change in the near future.

This species was historically found along the entire Gila River basin in Arizona, New Mexico, and Mexico (U.S. Fish and Wildlife Service 2005). Populations of Gila chub have slowly been disappearing, and they were listed as endangered with critical habitat and a draft recovery plan (U.S. Fish and Wildlife Service 2005). Gila chub are listed as G2 global conservation status and S2 (imperiled) in the state of Arizona (NatureServe 2015). The species is listed as species of greatest conservation need (Tier 1A) in Arizona (AGFD 2012). Tonto National Forest populations are declining or extinct; threats include loss of habitat due to water use practices and introduction of nonnative species (AGFD 2002c). Gila chub are currently are found within isolated reaches of the Tonto, in the Verde River Basin, Tonto Creek, and Aqua Fria River basin, part of the Lower Verde, Tonto Basin, and Agua Fria zones on the Cave Creek, Payson, and Pleasant Valley Ranger Districts. Critical habitat is designated on the Tonto in two small headwater reaches: Agua Fria (Silver and Sycamore creeks) and outside Tonto National Forest boundaries and planning context area in the Middle Gila and San Carlos zones. It has been extirpated from Fish and Cave Creeks on the Upper and Lower Salt River on the Tonto (AGFD 2002).

This species is commonly found in association with Gila topminnow, desert and Sonora sucker, and longfin and speckled dace and tends to seek out deeper waters near cover (AGFD 2002c). Habitat use varies from deeper, permanent pools or springs to vegetated margins and undercut banks, based on life stage. Reproduction occurs primarily from late spring into summer in streams but can extend into late winter in constant temperature springs. Spawning occurs over beds of submerged aquatic vegetation. Gila chub are omnivorous, preferring terrestrial and aquatic insects. At larger sizes, the Gila chub becomes piscivorous and has been found to consume speckled dace and other small cyprinids as available. Juveniles will feed throughout the day on insects and filamentous and diatomaceous algae (USFWS 2005).

Only small sections of designated critical habitat are present on Tonto National Forest. These are found in Silver and Sycamore Creeks on the Lower Verde zone. The primary constituent elements of critical habitat for Gila chub are:

- perennial pools with channel complexity and areas of open waters for passage between streambed vegetation;
- water temperatures appropriate for all life stages at appropriate timing;
- water quality criteria including low levels of contaminants and sediments and meeting physiological requirements;
- sufficient cover, including streamside vegetation, woody debris, boulders, and stable streambanks;

- absence of nonnative predators or competitors that are detrimental to Gila chub; and
- natural flow and hydrologic pattern, including periodic flooding.

Gila chub have been extirpated from much of their former habitat in Arizona due to introductions of nonnative species that compete with, and prey on, this species, as well as declines in perennial stream habitats. This has resulted in very small source populations available to augment recovery populations in isolated habitats. This decreases the potential for introgression and reduces resiliency to disturbance, which increases risk to viability of this species on the Tonto. Actions that can attenuate habitat loss trends include acquisition of water rights on National Forest System lands and implementing best management practices to improve watershed function. Vegetation treatments that reduce fire intensity and magnitude will also promote watershed resilience under changing climate conditions. Additionally, working in partnerships with the Arizona Game and Fish Department to remove invasive species and install migration barriers to protect native fish habitats will protect native species from the threats of nonnative species.

Risk for continued habitat loss for this species likely will remain high due to competition with introduced species, watershed condition, and projected increasing use pressures on surface waters (AGFD 2002c). Watersheds with perennial streams in the planning context area include the Agua Fria with 100 percent of 6th-level hydrologic unit code watersheds functioning at risk or in impaired condition (see the “Watershed Condition” section, table 109 on page 311). The Agua Fria watershed is also considered highly departed from reference condition for perennial stream miles containing nonnative species.

Gila trout (*Oncorhynchus gilae*): This species was listed as endangered in 1967 (under the Endangered Species Preservation Act of 1966) and was down-listed to threatened status in 2006 under the Endangered Species Act special rule for Arizona and New Mexico (U.S. Fish and Wildlife Service 1967, 2006). The species was reclassified to threatened status in New Mexico and Arizona in 2006 as part of a special rule under section 4(d) of the Endangered Species Act to allow production and stocking for recreational fishing in these states (U.S. Fish and Wildlife Service 2006). Gila trout is classified under NatureServe as G3 (vulnerable), and S1 (critically imperiled) in the State of Arizona due to its small range, habitat degradation, and competition and hybridization with introduced or invasive trout (NatureServe 2015). The species is presently listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012).

Gila trout were historically found in the Verde River watershed in the Tonto National Forest, but they were extirpated in the early 1900s. Critical habitat was not designated for Gila trout within the Tonto National Forest (U.S. Fish and Wildlife Service 2006). Fish were reestablished, and currently populations exist in Dude Creek of the Lower Verde zone on the Payson Ranger District, with proposals for additional recovery populations in the upper East Verde River and Tonto Creek and their associated tributaries (U.S. Fish and Wildlife Service 2015b, AGFD 2002d).

Gila trout generally use mountain headwater stream habitats, and, like other salmonid species, are sensitive to high stream temperatures, using habitats that rarely exceed 21 degrees Celcius (70 degrees Fahrenheit). Stream habitats generally are cobble and gravel substrates with high channel and cover complexity to provide pool depth and cover during stochastic events such as flooding and fire (U.S. Fish and Wildlife Service 2005, AGFD 2002). Gila trout feed on aquatic invertebrates and small fishes but seem to prefer adult and nymph stages of aquatic and terrestrial insects (AGFD 2002d).

Threats include development within and outside the Tonto National Forest boundary that result in groundwater depletion thus leading to reductions in streamflow and changes in water quality, in combination with climate change impacts. These aspects, though discussed in the assessment, are difficult to quantify and result in declines in habitat availability and quality. Additionally, management of nonnative fish species within waterways on the Tonto is conducted by the Arizona Game and Fish Department. Development on lands outside the Tonto National Forest in the context area is projected to continue, putting further stresses on groundwater and surface water resources that will continue to restrict available quality habitat for aquatic biota. Tonto National Forest and Arizona Game and Fish Department personnel are working collaboratively to identify suitable perennial sites for recovery reintroductions of this species to help increase the numbers of these small, isolated populations. Additionally, this species has been placed under a special 4(d) listing of the Endangered Species Act to allow fishable populations that could enhance community support for recovery. Other actions that can attenuate habitat loss trends include acquisition of water rights on National Forest System lands and implementing best management practices to improve watershed function. Vegetation treatments that reduce fire intensity and magnitude will also promote watershed resilience under changing climate conditions

Currently, recovery populations of Gila trout are small and disconnected with high risk of continued habitat loss due to increasing water demands and competition and predation from introduced species (AGFD 2002d). Watersheds with perennial streams within planning context area include the Lower Verde (with 67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired) and Tonto Basin (83.7 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired (see the “Watershed Condition” section, table 109 on page 311). Both watersheds are considered highly departed from reference condition for perennial stream miles containing nonnative species.

Gila topminnow (*Poeciliopsis occidentalis*): This species was listed as endangered in 1967 under the Endangered Species Preservation Act of 1966 (U.S. Fish and Wildlife Service 1967). The NatureServe conservation status for Gila topminnow is G3 (vulnerable) and S1 (critically imperiled) in the State of Arizona due to its small range, habitat loss, degradation, or a combination of those factors and competition and predation by with introduced or invasive fish species, particularly mosquitofish (NatureServe 2015). The species is presently listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012).

Historically, it was one of the most common fishes within the Gila River drainage in Arizona. Currently, the remaining extant native populations are outside the planning area in the Santa Cruz watershed; however, recovery work has allowed re-establishment of small, isolated populations that can be found or are proposed for reintroduction in all five zones of the Tonto National Forest in all six ranger districts (AGFD 2001b).

Gila topminnow occupy warmwater springs, cienegas, and small desert streams, It is found in the within Upper and Lower Salt, Agua Fria, and Lower Verde zones on the Tonto National Forest. This species prefers shallow, warmer waters with moderate currents and dense aquatic vegetation but is quite tolerant, and can withstand a wide range of water temperatures, salinities, alkalinities, and dissolved oxygen levels (AGFD 2001c).

Threats include development within and outside the Tonto National Forest boundary that result in groundwater depletion thus leading to reductions in streamflow and changes in water quality in combination with climate change impacts. These aspects, though discussed in the assessment, are difficult to quantify and result in declines in habitat availability and quality. Additionally, management of nonnative fish species within waterways on the Tonto is conducted by the Arizona Game and Fish Department. These fisheries have adverse effects to native fish populations from predation, competition, and potential disease transmission.

Gila topminnow were completely extirpated from the context area and so all remaining populations are part of recovery reintroductions into available springs, stock tanks, and stream, usually after treatment or isolation to prevent impacts from nonnative species. This has resulted in very small source populations used to augment recovery populations in isolated habitats. This decreases the potential of introgression and reduces resilience of this species to environmental changes. Actions that can attenuate habitat loss trends include acquisition of water rights on National Forest System lands and implementing best management practices to improve watershed function. Vegetation treatments that reduce fire intensity and magnitude will also promote watershed resilience under changing climate conditions. Additionally, working in partnerships with the Arizona Game and Fish Department to remove invasive species and install migration barriers to protect native fish habitats will protect native species from the threats of nonnative species.

Currently, recovery populations of Gila topminnow are small and disconnected with high risk of continued habitat loss due to increasing water demands, and competition and predation from introduced species (AGFD 2002d). Watersheds with perennial springs and cienegas within planning context area have moderate to high departure for watershed condition. These include the Upper Salt (97.8 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Lower Verde (67.5 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Tonto Basin (83.7 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Lower Salt (75 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired); Middle Gila (100 percent of 6th-level hydrologic unit code 6th-level hydrologic unit code watersheds are functioning at risk or impaired); and Agua Fria (100 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired). All six watersheds are considered highly departed from reference conditions for perennial stream miles containing nonnative species.

Headwater chub (*Gila nigra*) were proposed as threatened under the Endangered Species Act in December 2015 but this has not been finalized due to questions with taxonomy of the species (U.S. Fish and Wildlife Service 2016). NatureServe’s global status is G2 and state status is S2 (both imperiled) for headwater chub, due to its small range (NatureServe 2015). This species is presently listed as sensitive on the Region 3 forester’s list (USDA Forest Service 2013). Headwater chub are listed as State of Arizona Tier 1A species of greatest conservation concern (U.S. Fish and Wildlife Service 2015).

The taxonomic uniqueness of the three chub species currently federally listed or proposed for listing in the State of Arizona (Gila, roundtail, and headwater chub) is under review by the U.S. Fish and Wildlife Service and the date for final decisions have been extended (U.S. Fish and Wildlife Service 2016). The final decision, when issued, could substantially change the assessment results for these three species. Forest Service policy states that determinations be made based on the current status of the species as listed at the time of publication of forest documents, and we acknowledge this may substantially change in the near future. Critical habitat has not been designated for this species (U.S. Fish and Wildlife Service 2015).

Historically, this species occupied upper and middle reaches of larger streams and tributaries of the Verde River, Tonto Creek, and upper reaches of the Gila River upstream of the Tonto National Forest (U.S. Fish and Wildlife Service 2015). Currently, the species is found in the Tonto National

Forest in headwater streams of the Lower Verde (E. Verde River and Deadman Creeks) and the Tonto Basin (Tonto, Spring, and Marsh Creeks).

Headwater chub are associated with complex stream habitats that contain deeper pools and obstructions near riffles and runs with nearby cover, including root wads, boulders, and undercut banks. Generally, they are found in gravel and cobble substrates with small boulders. Preferred water temperature ranges from 20 to 27 degrees Celcius. Juvenile fish seem to be associated with shallow, low-velocity habitat with overhead cover (AGFD 2015). Chub are omnivorous, feeding on aquatic and terrestrial insects, terrestrial reptiles, plant material, and ostracods; their diets reflecting seasonal variability in prey. Juvenile chub feed almost exclusively on diatoms and algae (AGFD 2015).

Threats include development within and outside the Tonto National Forest boundary that result in groundwater depletion thus leading to reductions in streamflow and changes in water quality in combination with climate change impacts. These fish are found in large, complex river habitats that are greatly impacted by impoundments that restrict nutrients and alter flow, with numerous long-term ecological impacts. These aspects, though discussed in the assessment, are difficult to quantify and result in declines in habitat availability and quality. Additionally, management of nonnative fish species within waterways on the Tonto is conducted by the Arizona Game and Fish Department. These fisheries have adverse effects to native fish populations from predation, competition, and potential disease transmission. Actions that can reduce habitat loss trends include acquisition of water rights on National Forest System lands and implementing best management practices to improve watershed function. Vegetation treatments that reduce fire intensity and magnitude will also promote watershed resilience under changing climate conditions. Additionally, working in partnerships with the Arizona Game and Fish Department to remove invasive species and install migration barriers to protect native fish habitats will protect native species from the threats of nonnative species.

Planning area populations are declining or extinct, with high risk of continued habitat loss due to water use pressures and the presence and management for introduced species in key habitats (AGFD 2015a). Watersheds with perennial streams within planning context area have moderate to high departure from reference condition and include Lower Verde (67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired) and Tonto Basin (83.7 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired). Both watersheds are considered highly departed from reference for perennial stream miles containing nonnative species.

Loach minnow (*Tiaroga cobitis*): This species was up-listed to endangered from threatened status in March 2012 concurrently with the spikedace (U.S. Fish and Wildlife Service 2012). Critical habitat has been designated in Fossil Creek from the Fossil Diversion Dam downstream 13.8 miles on the Tonto National Forest. NatureServe’s rounded global status for loach minnow is G2 (imperiled) and Arizona state status is S1 (critically imperiled) due to extirpation from much of its former range, damming, stream channelization, excessive water withdrawal resulting in dewatering of habitat, and effects of nonnative fishes (NatureServe 2015). The species is listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012).

Historically, one of the most common species throughout the Gila River drainage, it is now restricted to isolated headwater reaches of the Gila River upstream of the Tonto National Forest. The species has been reintroduced in the planning area to Fossil Creek on the northern boundary of the Tonto; however, no natural reproduction has been observed (AGFD 2010, U.S. Fish and Wildlife Service 2012).

Loach minnow is a bottom-dwelling inhabitant of turbulent riffle habitats of the Gila River watershed that contain large cobble and boulder substrates. Loach minnows use the spaces between and behind larger substrates and spends their entire life history in these habitats. They are rare or absent from habitats where fine sediments fill the interstitial spaces. Loach minnows spawn from March through May. Adhesive eggs are attached under the downstream side of cobbles. Eggs incubate at 18 to 20 degrees Celcius and hatch in 5 to 6 days (AGFD 2010).

Critical habitat was designated in 2012 and includes Fossil Creek on the Tonto National Forest (U.S. Fish and Wildlife Service 2012). The primary constituent elements for loach minnow critical habitat are:

- habitat to support all life stages (perennial flow, appropriate habitat complexity with gravel, cobble, and rubble substrates, low fine sediments and embeddedness, water temperatures from 46.4 to 77 degrees Fahrenheit);
- abundant macroinvertebrate prey base;
- low pollutants;
- perennial flows with at least seasonal corridors between occupied habitats;
- lack of nonnative species or low levels to allow persistence; and
- normative flow regime.

Loach minnow populations have been impacted by dewatering of stream reaches by water diversions and dams, livestock grazing, habitat alteration, and introduced or invasive nonnative fish, especially catfishes and red shiner (AGFD 2010). Past forest management activities that have contributed to habitat degradation include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, stream diversion, and permitted livestock grazing. Management needs include conservation, protection, and monitoring of existing populations; reducing or eliminating impacts from nonnative predatory and competitive fish species; enhancement or restoration of select habitats within the historical range; and reintroduction into select historical habitats.

Loach minnow are under high risk of continued habitat loss due to water use pressures and the presence and management for introduced species in key habitats. Watersheds within the Lower Verde zone with perennial streams have moderate to high departure from reference condition; 67.5 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired. This watershed is also considered highly departed from reference condition for perennial stream miles containing nonnative species.

Razorback sucker (*Catostomus insignis*) is a federally protected species, listed as endangered in 1991 under the Endangered Species Act (U.S. Fish and Wildlife Service 1991). Critical habitat was designated in 1994 and includes portions of the Verde, Gila, and Salt Rivers (U.S. Fish and Wildlife Service 1994). The rounded global status for razorback sucker is G1 (critically imperiled) and state of Arizona status is S1 (critically imperiled) due to declines in distribution and abundance resulting from alteration and destruction of habitat by dams, and interactions with nonnative fishes (NatureServe 2015). The species is listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012).

Currently, small populations and critical habitat are found in the Verde River upstream of Bartlett Dam and the upper Salt River and upper Tonto Creek, upstream of Roosevelt dam within the Tonto National Forest (U.S. Fish and Wildlife Service 1991). Razorback sucker and their designated critical habitat are found in the Upper Salt and Lower Verde zones on Payson, Tonto Basin, Globe, and Cave Creek Ranger Districts (AGFD 2002e).

Razorback sucker use a variety of habitats in large rivers in the Colorado River basin. During spring, adult suckers use deep runs, eddies, backwaters and flooded off-channel environments, shallow runs and pools often associated with submerged sandbars in summer, and low-velocity runs, eddies, and pools in winter (AGFD 2002). Spawning typically occurs at temperatures greater than 14 degrees Celcius over bars of cobble, gravel, and sand substrates in rivers and over rocky shoals and shorelines in reservoirs. Nursery habitat typically occurs in quiet, warm, shallow water such as tributary mouths, backwaters, inundated floodplain habitats in rivers, and coves or shorelines of reservoirs (NatureServe 2015).

Critical habitat is designated in the upper Salt River and upper Tonto Creek, upstream of Roosevelt dam within the Tonto National Forest. The primary constituent elements of critical habitat for razorback sucker are:

- perennial waters of appropriate quality, quantity, and following a normative hydrograph;
- suitable habitat for all life stages, including larger river channels with bottomlands, side channels, and backwaters that provide larval rearing habitats; and
- suitable prey for all life stages with reduced influence from nonnative predators or competitors.

Threats to the species include altered flow hydrology and cold tailwater releases from reservoirs, water diversion, and predation by and competition with nonnative fishes (AGFD 2002e). Tonto National Forest management activities that have contributed to habitat degradation include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, stream diversion, and permitted livestock grazing. Management needs include amelioration of effects of reservoirs and nonnative fish species and continued monitoring of populations.

Razorback sucker are under high risk of continued habitat loss due to water use pressures and the presence and management for introduced species in key habitats. Watershed condition is moderate to highly departed where this species is found on the Tonto: Upper Salt (97.8 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired) and Lower Verde (67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired). Additionally, both watersheds are considered highly departed from reference condition for perennial stream miles containing nonnative species.

Roundtail chub (*Gila robusta*) were proposed for listing as threatened status concurrently with headwater chub in December 2015 under the Endangered Species Act (U.S. Fish and Wildlife Service 2015). The taxonomic uniqueness of the three chub species currently federally listed or proposed for listing in the State of Arizona (Gila, roundtail, and headwater chub) is under review by the U.S. Fish and Wildlife Service and the date for final decisions have been extended (U.S. Fish and Wildlife Service 2016). The final decision, when issued, could substantially change the assessment results for these three species. Forest Service policy states that determinations be made based on the current status of the species as listed at the time of publication of forest documents, and we acknowledge this may substantially change in the near future. Critical habitat has not been designated for this species (U.S. Fish and Wildlife Service 2015).

Roundtail chub historically were found throughout the Colorado River basin in mainstem and large tributary habitats. Currently, this species occupies less than 20 percent of their historic range, found in the upper Salt River (Ash, Cherry, Salome creeks) above Lake Roosevelt and the Verde River basin (Fossil, Roundtree Canyon creeks) within the Tonto National Forest planning area (Lower Verde, Upper Salt, and Tonto Basin zones in Globe, Tonto Basin, Cave Creek, and Payson Ranger Districts) (U.S. Fish and Wildlife Service 2015).

Roundtail chub occupy cool to warm water in mid-elevation streams and rivers where typical adult microhabitat consists of pools up to eight feet deep adjacent to swifter riffles and runs. Cover is usually present and consists of large boulders, tree rootwads, submerged large trees and branches, undercut cliff walls, or deep water. Smaller chub generally occupy shallower, low-velocity water adjacent to overhead bank cover. Spawning takes place over gravel substrate. Tolerated water temperatures approach 80 degrees Fahrenheit. Broadcast spawning occurs in early summer, often in or near habitats with submerged vegetation. Young chub feed on small insects, crustaceans, and algal films, while older chub move into moderate velocity pools and runs to feed on both terrestrial and aquatic insects along with filamentous algae. Large roundtail chub take small fish and terrestrial animals such as lizards that fall into the water (AGFD 2015).

Threats to roundtail chub include aquifer pumping, stream diversion, reduction in stream flows, and predation by and competition with nonnative fishes. Tonto National Forest management activities that have contributed to habitat degradation include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, dam construction and stream diversion, and permitted livestock grazing. Management needs include watershed and stream flow protection, restoration of habitats, and removal of nonnative fishes (AGFD 2015, U.S. Fish and Wildlife Service 2015).

This species is under moderate to high risk of continued habitat loss due to water use pressures and the presence and management for introduced species within occupied habitats (AGFD 2015b). Watershed condition is moderate to highly departed where this species is found on the Tonto National Forest: Upper Salt (97.8 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired) and Lower Verde (67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired). Additionally, both watersheds are considered highly departed from reference condition for perennial stream miles containing nonnative species.

Spikedace (*Meda fulgida*) were listed as threatened in 1986 and then up-listed to endangered in 2012 under the Endangered Species Act (U.S. Fish and Wildlife Service 2012). The species was once thought to be present in most of the Gila watershed, including the Salt, Verde, and Gila Rivers. Spikedace has a recovery priority number of 4C as this species is a monotypic genus with high threats to its persistence, low recovery potential, and economic conflicts between the species and development (U.S. Fish and Wildlife Service 2012). The rounded global status for spikedace under NatureServe is G2 (imperiled) and S1 for the State of Arizona due to its small range, declines in abundance and distribution (only 10 to 15 percent of its historical range), altered habitat, introduction of nonnative fishes, and groundwater pumping (NatureServe 2015). The species is listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012). Critical habitat for this species has been designated in the planning area from Horseshoe Reservoir upstream on the Verde River and in Tonto Creek upstream of Lake Roosevelt in the Lower Verde and Tonto Basin zones (U.S. Fish and Wildlife Service 2012).

Historically, the spikedace was common and locally abundant throughout the upper Gila River Basin of Arizona and New Mexico. Its distribution was widespread in large and moderate-sized rivers and streams in Arizona, including the Gila, Salt, and Verde Rivers and their major tributaries. Currently, the only known extant population on the Tonto is found in Fossil Creek as a result of recent reintroduction efforts.

Spikedace occupy mid-elevation, medium-sized perennial stream habitats usually less than 1 meter deep, with slow to moderate water velocities over sand, gravel, or cobble substrates. Adults often aggregate in shear zones along gravel-sand bars where rapid water borders slower flow, quiet eddies on the downstream edges of riffles, and broad shallow areas above gravel-sand bars. In winter, the species congregates along stream margins with cobble substrates. The erratic flow patterns of southwestern streams that include periodic spates and recurrent flooding are essential to the feeding and reproduction of the spikedace by scouring the sands and keeping gravels clean. Spikedace larvae and juveniles tend to occupy shallow, peripheral portions of streams with slow currents and sand or fine gravel substrates, but they will also occupy backwater habitats. The young typically occupy stream margin habitats where the water velocity is less than 0.16 feet per second (5 centimeters per second) and the depth is less than 1.96 inches (5 centimeters). Spawning extends from mid-March into June and occurs in shallow (less than 15 centimeters centimeters or 5.9 inches) riffles with gravel and sand bottoms and moderate flow. By mid-May, most spawning has occurred; although, in years of high water flows, spawning may continue into late May or early June. Spikedace feed primarily on aquatic and terrestrial insects (AGFD 2013, U.S. Fish and Wildlife Service 2012).

Critical habitat designated on the Tonto includes perennial reaches of the Verde River to the Fossil Creek confluence, Fossil Creek itself, and sections of Tonto Creek upstream to Spring Creek (U.S. Fish and Wildlife Service 2012). The primary constituent elements of critical habitat for spikedace are:

- suitable perennial flow habitat for all life stages, including variable stream flows, glides, runs, riffles, the margins of pools and eddies, and backwater components over sand, gravel, and cobble substrates with low or moderate amounts of fine sediment and substrate embeddedness;
- suitable and abundant aquatic macroinvertebrate prey;
- streams with no or low levels of pollutants;
- perennial waters of appropriate quality, quantity, and connectivity;
- reduced or eliminated impacts from nonnative predators or competitors; and
- perennial flows following a normative hydrograph.

Threats to the species include stream flow depletion, diversion, habitat alteration and competition with nonnative crayfishes, and predation by and competition with nonnative fishes, especially red shiner. Tonto National Forestmanagement activities that have contributed to habitat degradation include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, stream diversion, and permitted livestock grazing. Management needs include conservation, protection, and monitoring of existing populations; amelioration of impacts from nonnative predatory and competitor species; enhancement or restoration of select habitats within its historical range; and further reintroduction into select historical habitats (AGFD 2013b).

Spikedace are under high risk of continued habitat loss due to water use pressures and the presence and management for introduced species in key habitats. Watersheds with perennial streams within planning context area have moderate to high departure from reference condition: Lower Verde (67.5 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired) and Tonto Basin (83.7 percent of 6th-level hydrologic unit code watersheds are functioning at risk or impaired). Both watersheds are also considered highly departed from reference for perennial stream miles containing nonnative species.

Mammals

Mexican wolf (*Canis lupus baileyi*): The Mexican wolf is a habitat generalist with 1,145,142 acres of primary potential habitat occurring on portions of the six ranger districts. The rest of the Tonto National Forest is considered secondary potential habitat (1,781,664 acres). Approximately 20 percent of both primary and secondary potential habitat for the species is in portions of the Four Peaks, Hellsgate, Mazatzal, Pine Mountain, Salome, Salt River Canyon, Sierra Ancha, and Superstition Wilderness Areas. Currently, the potential habitat on the Tonto National Forest is not known to be occupied by any active wolf packs; however, in 2014, the interagency field team photographed a wolf on a trail camera in the northeastern part of the Tonto (U.S. Fish and Wildife Service 2015).

Mexican wolves may occur in a variety of habitats but generally prefer mountain woodlands and avoid low deserts. Wolves also require habitats that provide ungulate prey, water, hiding cover, and suitable den sites. While the wolf is not currently established on the Tonto National Forest, potential habitat can be found in three local zones: Upper Salt, Tonto Basin, and Lower Verde. Corresponding ecological response units in the planning area include Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Grass, Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, Mixed Conifer - Frequent Fire, and Riparian. These ecological response units are range from moderately to highly departed (Pinyon-Juniper Evergreen Shrub 76 percent, Pinyon-Juniper Grass 35 percent, Ponderosa Pine - Evergreen Oak 73 percent, Ponderosa Pine Forest 95 percent, Mixed Conifer - Frequent Fire 62 percent, and Riparian). However, threats to habitat are not currently considered a main threat to wolves at this time (U.S. Fish and Wildlife Service 2010). Primary threats to the current population of wolves involve regulatory issues, inbreeding, and illegal shooting (U.S. Fish and Wildlife Service 2010).

As the wolf population grows, the interagency field team predicts wolves will disperse into the Payson area on the Tonto National Forest. The wolves may establish packs and home ranges. At this time, no future translocations are planned in zone 2 (John Oakleaf, personal communication, 2015). The U.S. Forest Service serves as a cooperating agency in the Mexican wolf reintroduction program as governed by memorandum of understanding last updated in 2013. Tonto National Forest personnel, therefore, have the responsibility to cooperate with the reintroduction project.

While reintroduction efforts have resulted in an established population of Mexican wolves in the recovery area, the population is not thriving. While no single threat is considered responsible for the slow recovery process, the combined effects of regulations associated with boundaries and livestock depredation, lack of an up-to-date recovery plan, illegal shooting, and inbreeding have hindered the recovery of the Mexican wolf (U.S. Fish and Wildlife Service 2010).

Lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae)* is a federally endangered species distributed across southwestern Arizona. While there are no known roost areas on the Tonto, potential foraging habitat does occur. This potential habitat was refined in coordination with the U.S. Fish and Wildlife Service in March 2015 and includes all acres of desert communities between 1,600 and 7,500 feet elevation (that is, desert scrub, desert grasslands, and Madrean encinal woodland communities). In total, there are 767,029 acres of potential foraging habitat in the planning area; however, actual population status on the Tonto is not known.

This bat requires caves and mine sites as roosting habitat. They are associated with Sonoran desert scrub communities, with special dependence on saguaros and paniculate agaves. They primarily use the nectar and pollen from these species from early to late summer but will also take ripe cactus fruit when available (U.S. Fish and Wildlife Service 2016).

The lesser long-nosed bat is mostly likely to be found in the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit, which has an increased risk of fire (56 percent fire regime condition class III) and in Interior Chaparral (78 percent fire regime condition class II).

Habitat fragmentation is a significant concern for this bat species due to its migratory nature. For much of the year, the bats reside in central and southern Mexico, but they migrate north to northern Mexico and southern Arizona to have their young. They then rely on suitable foraging habitat in order to make the return trip to their wintering grounds. Human development or land use may create barriers between roost sites and foraging areas or may alter the composition of foraging species. Disturbance or destruction of roosting areas is also a concern for the lesser long-nosed bat (U.S. Fish and Wildlife Service 2016).

The Tonto National Forest is responsible for managing potential roosting and spring foraging habitat. If occupied sites are identified, measures can be taken to manage sites. Tonto National Forest personnel currently consult with the U.S. Fish and Wildlife Service on management activities that may affect important bat habitat.

In January 2016, the U.S. Fish and Wildlife Service proposed to delist the lesser long-nosed bat due to recovery. This motion was filed in part due to recent taxonomic updates and changed conservation status due to reduced risk. The motion also serves as a 12-month finding on a petition to reclassify the subspecies from endangered to threatened. If the current listing status changes, the bat will be considered as a potential species of conservation concern (U.S. Fish and Wildlife Service 2016).

Ocelot *(Leopardus pardalis*) is a federally endangered species with potential habitat on the Tonto National Forest. In coordination with the U.S. Fish and Wildlife Service, the Tonto National Forest personnel currently recognize approximately 226,242 acres of potential ocelot habitat on the Tonto. Potential habitat is partially based on the location of a young adult male ocelot that was killed by a vehicle in April 2010 on U.S. Highway 60 near the Tonto National Forest boundary. Ocelot habitat in the planning area could include Interior Chaparral, Madrean Encinal Woodlands, and Semi-Desert Grasslands ecological response units on the Globe Ranger District (Timbadia, personal communication, 2015). Five individual ocelots have been detected in Arizona between 2009 and 2015. The remaining U.S. population occurs in south Texas and was estimated to have 53 individuals as of 2015. Critical habitat has not been defined by the U.S. Fish and Wildlife Service because the designation was not considered to be in the best interest of the species (U.S. Fish and Wildlife Service 2016).

Ocelot habitat generally requires greater than 75 percent vegetative cover. Habitat types used by ocelot vary greatly across its range, though most are heavily wooded (U.S. Fish and Wildlife Service 2016). Potential habitat in the planning area is most associated with the Madrean Ecinal Woodland ecological response unit. Seral state departure for the Madrean Encinal Woodland ecological response unit is moderate and high for Semi-Desert Grassland ecological response unit, putting potential dispersal habitat at risk for the species. Habitat conversion, fragmentation, and isolated populations are the primary issues impeding ocelot recovery. Man-made boundaries, including roads and highways, agricultural fields, and the U.S.-Mexico border, make dispersal challenging. Based on current management, departure in the Madrean Encinal Woodland ecological response unit is projected to stay high (50 percent) in the future. However, even more challenging for the ocelot is the projected urbanization around the planning area. The Tonto National Forest may provide potential habitat free from the dramatic alterations found elsewhere in the ocelot's range. However, extant populations in Mexico and Texas are largely disconnected from available habitat in the planning area. Reproductive isolation is a concern for these disjunct populations found in the southern U.S. (U.S. Fish and Wildlife Service 2016).

Due to the challenges of habitat connectivity associated with human populations near the plan area, the status is of the ocelot in the planning area is unlikely to change in the near future. This small cat is listed as endangered throughout its range which includes 22 countries (U.S. Fish and Wildlife Service 2016).

Plants

Arizona cliffrose (*Purshia subintegra*) is known from 4 disjunct sites in Arizona, found only at Tertiary limestone lakebed deposits. The Arizona cliffrose was listed as endangered in 1984 and the Tonto National Forest has one of the recovery units located near Horseshoe Lake in the Lower Verde zone. Populations are found in the Mojave Sonoran Desert Scrub and Sonora-Mohave Mixed Salt Desert Scrub ecological response units where winters are mild and summers are hot, with an average of 9 to 34 inches of precipitation evenly distributed between summer and winter rainfall periods. Threats that resulted in the listing of the species include live stock grazing, poor reproduction, mineral exploration and development, off-road vehicle use, urbanization, pesticides, and inundation (U.S. Fish and Wildlife Service 1995).

While current conditions show low seral state departure for the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit, habitat degradation is apparent with more than 80 percent of soils rated as impaired to unsatisfactory. Nearly 50 percent of soils in Mojave Sonoran Desert Scrub ecological response unit are impaired. Impaired and unsatisfactory soils can result in unstable soils with reduced hydrological function and nutrient cycling. Recreational impacts are high at the surrounding areas on the Tonto National Forest within suitable habitat. Climate change (increasing aridity, drought) is likely to further stress habitat conditions and potentially impact Arizona cliffrose habitat and populations.

The current 1985 Forest Plan does not provide management direction for the Arizona cliffrose because the Horseshoe population was not discovered until 1985 when the plan was being finalized. Instead, general guidelines and management direction were developed. These include increasing population levels and preserving habitat for known threatened and endangered species. Forestwide prescriptions that pertain to Arizona cliffrose include identifying, surveying, and analyzing habitat. Projects are required to be cleared for all listed, proposed, and candidate plant species.

Arizona hedgehog cactus (*Echinocereus triglochidiatus* var. *arizonicus*) is known to occur in Gila and Pinal counties and was listed as endangered in 1979. Arizona hedgehog cactus is a perennial succulent found at rugged, steep-walled canyons; boulder-pile ridges; and slopes (AGFD 2003). Plants are also found scattered on open slopes, in narrow cracks between boulders and in the understory of shrubs (less common among dense shrubs). Plant communities include chaparral (Interior Chaparral ecological response unit), madrean woodlands (Madrean Encinal Woodland ecological response unit) and semi-desert grasslands (Semi-Desert Grassland ecological response unit).

Mining in the Globe-Miami and Superior areas are considered by the U.S. Fish and Wildlife Service to be the primary threat to the species. Other threats include livestock grazing and tramping; however, damage from javelinas is more frequent and problematic. The greatest man-induced threat to the species is collection for landscaping and collection for the hallucinogenic substance dimethyltryptamine. With the exception of Interior Chaparral, the associated ecological response units are highly departed from reference conditions and 100-year projections show the same departure ratings. While current and projected conditions show low seral state departure for Interior Chaparral, 78 percent of acres are classified as fire regime condition class II – indicating a moderate departure in fire regime. As a result of fire suppression and exclusion, some areas may experience very hot fires due to the build-up of dead fuel matter. However, most plants are located in areas where fires are less of a concern (rocky habitats with lower fuel loads). A large proportion of the habitat does have high vulnerability to climate change effects (reference “Climate Change” section) and increased drying trends may alter the microsite conditions where populations are found.

A conservation assessment and plan for the Arizona hedgehog cactus was developed in 1996. Management since its listing in 1979 has focused on conducting surveys to determine distribution on the Tonto National Forest and to protect habitat during implementation of resource management activities on the Tonto. Another management strategy of propagation and out-planting of nursery grown plants (at Boyce Thompson Arboretum) to reinforce native populations was never fully implemented.

Reptiles

Narrow-headed gartersnake (*Thamnophis rufipunctatus*) is a federally threatened species and is currently known to occur on the Payson and Pleasant Valley Ranger Districts. Approximately 29,931 acres of potential habitat for narrow-headed gartersnake occurs on Cave Creek, Globe, Payson, Pleasant Valley, and Tonto Basin Ranger Districts. This includes portions of the East Verde, Salt, and Verde Rivers and Canyon, Haigler, Houston, and Tonto Creeks. Populations are described as low to very low densities in potential habitat on the Tonto National Forest. Narrow-headed gartersnakes may disperse into the East Verde from the occupied Verde River to augment the population, but the East Verde River population likely occurs as a low to very low density. On the East Verde River, numerous records document narrow-headed gartersnakes occupying habitats from the 1980s to early 1990s. Rosen and Schwalbe (1988, Appendix II) invested approximately 20 person-search hours from 1985 to 1986 surveying the East Verde River, The surveys produced 12 observation records for narrow-headed gartersnakes. Holycross and others (2006, pp. 21–22) spent 182 person-search hours and 20,757 trap-hours from 2004 to 2005 surveying the East Verde River with no observations of narrow-headed gartersnakes.

Narrow-headed gartersnakes require perennial streams with native fish which make up 90 percent or more of their diet. This highly aquatic snake is associated with clear, rocky streams at elevations between 2,300 and 8,000 feet. They prefer pools and riffles as primary habitat, tending to avoid silty waters and crayfish. Although they depend on aquatic habitat, the snakes use upland habitat in fall, spring, and during hibernation. The narrow-headed gartersnake uses basking areas that provide a quick escape into the water or rocks. While they may opportunistically use dammed reservoirs to forage, these areas are generally avoided due to the presence of predator sport fish. Temperature requirements are not well studied for the species, but it is estimated that they are active between 52 and 89 degrees Fahrenheit. Narrow-headed gartersnakes are considered fish-eating specialists and primarily prey on native species such as the Sonora sucker (*Catostomus insignis*), desert sucker (*C. clarki*), speckled dace (*Rhinichthys osculus*), roundtail chub (*Gila robusta*), Gila chub (*Gila intermedia*), and headwater chub (*Gila nigra*). Most of these are currently listed as endangered or threatened species (U.S. Fish and Wildlife Service 2014).

The narrow-headed gartersnake may be associated with all four riparian ecological response units named in our assessment; however, it appears most likely to use higher elevation ecological response units, including Fremont Cottonwood – Conifer, Cottonwood Group, and Ponderosa Pine/Willow. Currently, these ecological response units are largely functioning at high risk. Throughout the planning area, 31 percent of riparian areas are classified as unstable, while an additional 51 percent are considered impaired. Only 18 percent of streams assessed were considered stable.

Recruitment problems for narrow-headed gartersnakes were observed in the East Verde River during the mid-1980s, evidenced by detections dominated by the largest age class (Rosen and Schwalbe 1988, p. 45). The introduction and establishment of nonnative species has led to a dramatic decline in the prey base used by this snake species. Although they may prey on some introduced fish species, these same fish, as larger adults, may prey on young snakes. Makinster and Staffeldt (2013, p. 4) stated green sunfish, largemouth bass, and smallmouth bass appear to be the biggest threat to native species within the lower reaches of the East Verde River. In other areas, aggressive brown trout may pose a threat to narrow-headed gartersnake neonates. Habitats used by this snake are also frequently subject to pressure from high recreational use.

Populations of narrow-headed gartersnakes are projected to decline over time due to continued pressure by nonnative species in limited habitat. Additionally, riparian systems are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas (U.S. Fish and Wildlife Service 2014). The Tonto National Forest personnel are responsible for managing grazing, recreation, and groundwater pumping that can affect riparian areas. Management activities are conducted in consultation with the U.S. Fish and Wildlife Service.

Populations of narrow-headed gartersnake are projected to decline due to the cumulative effect of nonnative species and changes to the landscape, resulting in isolation between populations. Increased decline may lead to extirpation on the Tonto National Forest and a change in the currently listed status.

Northern Mexican gartersnake (*Thamnophis eques megalops*) is a federally threatened species and has been documented in Tonto Creek (AGFD HDMS 2012). Several observations of the species were documented in 1981, 1985 to 1986, and 1992. However, the population is considered to be at a low density and likely not viable (U.S. Fish and Wildlife Service 2013). Arizona Game and Fish Department's heritage database identified an element occurrence record of the northern Mexican gartersnake in the project area near the Town of Payson. While surveying for the Chiricahua leopard frog in 2011, district staff observed terrestrial gartersnakes at Piper Springs near the tailrace of the East Verde River and east tributary of West Verde River near Washington Park. This suggests there is habitat to support gartersnake species, and there may be some habitat components present that support the northern Mexican gartersnake.

These snakes occur at elevations between 130 and 8,497 feet. They are a riparian obligate, most commonly found in ciénagas, streams, rivers, and riparian woodlands and forests. They are most active in temperatures between 71 and 91 degrees Fahrenheit, with peak activity from June to September. Although primarily aquatic, northern Mexican gartersnakes will use terrestrial habitat up to 528 feet from water for dispersal, reproduction, and hibernation. Diet consists primarily of native amphibians and fish, including Chiricahua and lowland leopard frogs, Gila topminnow, desert pupfish, Gila chub, and roundtail chub (U.S. Fish and Wildlife Service 2014).

The northern Mexican gartersnake may be associated with all four riparian ecological response units named in our assessment, including Desert Willow, Fremont Cottonwood – Conifer, Cottonwood Group, and Ponderosa Pine/Willow. Currently, these ecological response units are largely functioning at high risk. Throughout the planning area, 31 percent of riparian areas are classified as unstable, while an additional 51 percent are considered impaired. Only 18 percent of streams assessed were considered stable.

Threats include dewatering of perennial waterways, introduction of nonnative fish, and competition from nonnative bullfrogs and crayfish. In conditions where native prey are not available, it appears northern Mexican gartersnakes will eat nonnative prey such as sportfish, bullfrogs, and nonnative snails; however, there are concerns that many of these are incompatible with the snake and may lead to increased mortality. The continued exposure to competition and predation by introduced nonnatives will likely continue to strain extant populations of northern Mexican gartersnake (U.S. Fish and Wildlife Service 2014). In addition, aquatic and riparian habitats in the planning area are likely to continue to be stressed from climate-related drought, increasing water demands from a growing human population, and higher risk of catastrophic fire in upland areas. Tonto National Forest personnel manage grazing, recreation, and groundwater pumping in these systems.

Decline due to the threat of nonnative species may lead to extirpation on the Tonto National Forest and a change in the currently listed status.

Potential Species of Conservation Concern

Information on the species below indicates substantial concern about a species' capability to persist over the long term in the plan area. All species listed met one or more of the initial requirements for identifying species of conservation concern and a number of sources were consulted to determine whether the species was at-risk on the Tonto National Forest. For all potential species of conservation concern candidates, the ecological conditions for persistence were compared against the current and future trend of those conditions on the Tonto as well as other key risk factors associated with those conditions. Consideration was also given to factors not evaluated by the assessment. Concerns for persistence of the following species on the Tonto National Forest are described in the following sections.

Amphibians

Lowland leopard frog (*Rana yavapaiensis*): Potential habitat in the planning area for the lowland leopard frog occurs below the Mogollon Rim in riparian areas, particularly in unregulated streams subject to periodic floods.

Stressors on water resources, including drought, fire, and an increased demand for water, are expected to continue into the future. The fire regime condition class III for the Sonoran Palo Verde-Mixed Cactus Desert Scrub and Semi-Desert Grasslands ecological response units is 56 percent and 46 percent, respectively. For the upper elevation ecological response units, which can affect riparian areas downstream where this species is found, the fire regime condition class III is high for both Ponderosa Pine Forest (51 percent) and Ponderosa Pine - Evergreen Oak (46 percent) ecological response units. Large-scale wildfires are often followed by large-scale scouring events within the fire boundaries. The resulting sediment load could affect large portions of lowland leopard frog populations.

Though currently stable in most of central Arizona, declines and extirpations have occurred due to chytrid fungal infection, nonnative species interactions (bullfrogs, crayfish), changes in the overall hydrologic conditions (for example, flows, flooding, diversions), and scouring from floods following fires. Risk for this species is considered high and will likely increase due to stressors on permanent water sources, disease, nonnative species, and large-scale fire events. The lowland leopard frog has declined significantly in southeastern Arizona, and the threat to species persistence is considered high (C. Akins, AZGFD, personal communication, 2016).

Birds

American dipper (*Cinclus mexicanus*): The American dipper's breeding range was found to have significantly contracted based on historical observations in Arizona (Corman and Wise-Gervais 2005). Historically this species bred along the larger creeks flowing down from the Mogollon Rim in the Tonto National Forest. American dippers are typically found along very clear and swift perennial drainages, often with an abundance of waterfalls and boulders. This species requires streamside nest sites in the form of large rocks, cliffs, and bridges with overhanging ledges and crevices.

Vegetative habitat along the drainage is not as important to the American dipper as stream clarity and stream bottom composition for ease of foraging and aquatic prey abundance (Corman and Wise-Gervais 2005). The most likely causes for the contraction of their breeding range are reduced flows, scouring following wildfires, sedimentation, and other hydrologic changes (T. Corman, personal communication, July 28, 2016). Another major factor was the introduction of crayfish, which reduced aquatic invertebrates the American dippers feed to their offspring.

The typical ecological response unit found along the creeks draining the Mogollon Rim is the Fremont Cottonwood-Conifer riparian ecological response unit. This ecological response unit is at high risk from wildfire due to neighboring vegetation in fire regime condition classes II and III. The combination of low population size, limited breeding habitat, high risk of wildfire, and threats from invasive species suggest this species is at-risk on the Tonto National Forest.

Broad-billed hummingbird (*Cynathus latirostris*): Over the past few decades, the broad-billed hummingbird has expanded its breeding range northward to now include the Tonto National Forest, where it reaches the northern limit of its range (Corman and Wise-Gervais 2007). This species is known as a breeder on the Tonto National Forest in only a couple of southern locations.

This species requires broadleaf riparian woodlands, mountain and foothill canyon bottoms, mesquites bosques, and heavily wooded washes. Its preferred lower-elevation habitat includes cottonwood, netleaf hackberry, willow, and velvet mesquite. Upper-elevation habitat is sycamore, Arizona walnut, alligator juniper, and various madrean evergreen oaks (Corman and Wise-Gervais 2005). The corresponding ecological response units on the Tonto National Forest are Desert Willow riparian and Pinyon-Juniper Evergreen Shrub (Corman and Wise-Gervais 2005).

There are currently no data about the departure of the Desert Willow riparian ecological response unit; however, the upland conditions encompassing the ecological response unit are projected to be in high departure and class III for fire regime condition. The Pinyon-Juniper Evergreen Shrub ecological response unit is projected to become more of a closed state and likely to result in an increase in insects, pathogens, and wildfire. Broad-billed hummingbirds are reproductively isolated on the Tonto National Forest, occurring in small numbers at a limited number of spread out breeding locations. If a wildfire occurs at one of the few breeding locations, the species could become locally extirpated. The small and isolated populations and projected trend for the species' breeding habitat make it at-risk on the Tonto National Forest.

Clark's grebe (*Aechmophorus clarkii*) is a winter resident on the larger reservoirs of the Tonto National Forest. The only known regular breeding population of this species in central Arizona is at Roosevelt Lake (T. Corman, personal communication, July 28, 2016). Not much is known about the population trend of this recently recognized (in 1985) species. This species prefers large areas of open water and emergent or flooded vegetation (cattails and bulrushes) for nest cover (Corman and Wise-Gervais 2005).

The biggest threat to the Roosevelt Lake breeding population is the water level on Roosevelt Lake (T. Corman, personal communication, July 28, 2016). This species begins nesting around the same time the water levels are lowered on the lake. When this happens, nests built in flooded vegetation are no longer flooded and the birds cannot access their nest. This reduces the likelihood of successfully raising offspring. In addition, this species is more susceptible to human recreation activities on the lake (Corman and Wise-Gervais 2005).

Clark's grebes are highly social on their breeding grounds; they nest in high density colonies. If the population declines too much, the colony may become too small for them to colonially nest at the lake. This species should be considered at-risk of persisting over the long term on the Tonto National Forest due to limited breeding range and conflicts with humans at Roosevelt Lake.

Elf owl (*Micrathene whitneyi*): The population of elf owls faced a drastic decline in Arizona and California perhaps due to habitat destruction. Elf owls have declined as habitat has been developed for homes and agriculture. Riparian areas in their range are threatened by water diversion for agriculture and household use and invasive plants, especially salt cedar (American Bird Conservancy 2016).

Elf owls are known to reside throughout the range of arid deserts, thorn scrub, open pine-oak forests, deciduous riparian woodlands, adjacent tablelands, and mesquite at elevations from 2,000 to 7,200 feet. These owls can also be found in deserts that are abundant in giant saguaro so they can find their woody habitats.

Historically, natural occurring fuel loads were discontinuous patches, limiting the spread of fire. Currently Sonoran desert ecological response units are considered to have a high departure in fire regime condition class III (55 percent). For example the Cave Creek Fire of 2005 killed 20 percent of cacti, reducing potential nesting habitat in Sonoran cacti. This species should be considered at-risk of persisting over the long term on the Tonto National Forest due to the risk of habitat loss from wildfire and water diversion for development.

Desert purple martin (*Progne subis*): Two subspecies of purple martin breed on the Tonto National Forest. The subspecies *Hesperia,* or desert purple martin, is of conservation concern on the Tonto National Forest as these birds are regular breeders on the Tonto and have undergone a long-term decline across their range (NatureServe 2016).

The purple martin's preferred habitat is densely vegetated Sonoran Desert scrub (Sonoran Mid-Elevation Desert Scrub ecological response unit) where large, cavity-filled saguaros are present (Corman and Wise-Gervais 2005). This habitat only makes up 4 percent of the Tonto National Forest, and currently this ecological response unit is undergoing moderate departure (52 percent) and is in fire regime condition class III in part due to the establishment of exotic annuals that create uncharacteristic wildfires. These uncharacteristic wildfires have caused a shift from native vegetation to shrub communities, leaving less potential breeding habitat for the desert purple martin.

Other threats to populations of purple martins are competition with nonnative invasive species (such as the house sparrow and European starling) and habitat transformation that reduces the amount of mature saguaro cacti. The combination of competition from nonnative and invasive species, breeding habitat departure, and land transformation make the desert purple martin at-risk on the Tonto National Forest.

Gilded flickers (*Colaptes chrysoides*) are found in lush Sonoran Desert habitats with a high density of tall saguaros. It was reported in the Arizona Breeding Bird Atlas that 90 percent of gilded flickers documented used saguaro cacti for nesting (Corman and Wise-Gervais 2005). Currently this species has seen a statistically significant decrease over the last 40 years, a 60.2 percent decline in population (BirdLife International 2016).

The major threats to this species persisting in the Tonto National Forest are uncharacteristic wildfires and land transformation. The Sonoran Desert Scrub ecological response unit is currently in low departure but is projected over 100 years to be in high departure (71 percent). This ecological response unit has been classified in fire regime condition class III (55 percent), showing that the fire regime is highly departed, resulting in higher intensity fires that decimate desert plants (saguaros) that have not evolved to withstand high-intensity fires.

The urban area of Phoenix will continue to expand into the upland Sonoran Desert habitat this species prefers and will degrade it, making it important for the Tonto National Forest to protect the upland Sonoran Desert habitat it contains as a refuge for this species. During the Arizona Breeding Bird Surveys, it was found this species does not tolerate densely populated urban or rural neighborhoods, even those with saguaros (Corman and Wise-Gervais 2005). The steep decline in population along with the continued sprawl of the Phoenix metropolitan area and departed fire regimes in the gilded flicker's habitat make the species at-risk on the Tonto National Forest.

Lewis's woodpecker (*Melanerpes lewis*) is closely associated with open ponderosa pine forests. The only breeding records of this species found on the Tonto National Forest were in the Sierra Ancha Mountains near Young, Arizona. At other times of the year, Lewis's woodpeckers use the Tonto rather irregularly (Corman and Wise-Gervais 2005).

The ecological conditions necessary for this species includes open ponderosa pine or riparian woodlands and settings offering a brushy understory, open foraging areas, and snags for perching (Corman and Wise-Gervais 2005). The two ecological response units this species prefers (Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest) are both in high departure in most local scales on the Tonto National Forest. The population trend of Lewis's woodpeckers shows it declining in abundance, possibly by 60 percent or more since the 1960s (NatureServe 2016). Factors that can be influenced by management are the presence of snags, brushy understories, and open areas. These criteria are typically met in recently burned areas.

The future trend for the Ponderosa Pine - Evergreen Oak ecological response unit on the Tonto National Forest predicts closed-canopy states will continue, which will result in large patch sizes reducing the number of open areas, snags, and brushy understory. Due to the combination of declining populations, high departure from reference conditions in the species' preferred habitat, and low population numbers on the Tonto National Forest, Lewis's woodpeckers should be considered at-risk on the Tonto National Forest.

MacGillivray's warbler (*Geothlypis tolmiei)* breeds in the high-elevation drainages along the Mogollon Rim (Corman and Wise-Gervais 2005). The ecological conditions necessary for the species to breed include cool, shaded mountain drainages with a mixture of coniferous and deciduous trees and shrubs (Corman and Wise-Gervais 2005).

This described breeding habitat falls under the Ponderosa Pine-Willow Riparian ecological response unit. This is a rare habitat, accounting for only 7 percent of the Tonto National Forest. Currently the Ponderosa Pine-Willow ecological response unit is undergoing moderate departure. The upland conditions surrounding this ecological response unit are currently in high departure and predicted to be in moderate departure in 100 years (the fire regime condition class is class III).

MacGillivray's warblers are at risk of no longer breeding on the Tonto National Forest due to a combination of factors. The high departure of the surrounding habitat could result in uncharacteristic wildfires that could make the species preferred habitat more open and hot, rendering it unsuitable for breeding. There is limited available and potential breeding habitat for this species. The limited breeding habitat available is undergoing moderate departure and is prone to wildfire, and there is a low breeding population size. These factors make this species at-risk on the Tonto National Forest.

Olive-sided flycatchers (*Contopus cooperi*) are declining throughout their range and are listed by NatureServe as an S2B and by the International Union for the Conservation of Nature as near threatened (Corman and Wise-Gervais 2005, NatureServe 2016, BirdLife International 2016). This flycatcher is an uncommon breeder in the state with about 3 percent of the breeding bird atlas blocks reporting breeding evidence, some occurring along the rim country of the Tonto National Forest (Corman and Wise-Gervais 2005).

The ecological conditions necessary for this species in the plan area include open mixed conifer forests of Doulas fir, white fir, ponderosa pine, and occasionally in ponderosa pine-Gambel's oak associations. This habitat description translates to Mixed Conifer - Frequent Fire and Ponderosa Pine Forest ecological response units. The current conditions of the ecological response units are moderate departure for Mixed Conifer - Frequent Fire and high departure for Ponderosa Pine Forest. These ecological response units are projected to shift from mature, tall trees to small, closed-canopy habitats, which conflicts with this species' preference for edge habitat with tall prominent trees and snags from which to forage. In addition, there is a shift towards larger patch sizes, reducing the amount of available habitat for this species. These specific habitat requirements can be influenced by Tonto National Forest management through the use of prescribed burns, which increases edge habitat preferred by this species (Corman and Wise-Gervais 2005).

The combination of declining populations and predictions of reduced available breeding habitat on the Tonto indicate this species is at-risk over the long-term on the Tonto National Forest.

Pacific wren (*Troglodytes pacificus*): The reclassification of the winter wren into two species has left many questions regarding the recently named Pacific wren. This reclassification occurred after the completion of the Arizona Breeding Bird Atlas surveys and breeding records for the Tonto National Forest can be assumed to be Pacific wrens and not winter wrens (T. Corman, personal communication, July 28, 2016).

The Pacific wren is at the southern limit of its breeding range on the Tonto National Forest, with two of four possible breeding records in Arizona being on the Tonto along the Mogollon Rim

(Corman and Wise-Gervais 2005). The ecological conditions where the species has been found breeding on the Tonto include cool, damp, shadowy forest ravines along steep, narrow drainages with an abundance of fallen trees, rotting logs, stumps, limbs, and dense tangles. Typical vegetation includes stands of Douglas fir, white fir, ponderosa pine, Gambel’s oak, and bigtooth maple with an understory of downed trees, forest litter, and boulders, interspersed with patches of various ferns, moss, and forbs (Corman and Wise-Gervais 2005).

The type of habitat preferred by this species is rare on the Tonto National Forest and can be placed in the Ponderosa Pine/Willow ecological response unit, which accounts for 7 percent of the Tonto. The upland condition surrounding this riparian ecological response unit is in fire regime condition class III and very prone to uncharacteristic wildfires. The most imminent threat to this species on the Tonto National Forest is wildfire. A wildfire burning along the Mogollon Rim could alter the Pacific wren’s breeding habitat into a much drier, open forest, and potentially extirpate the breeding population in the Tonto National Forest and in the state as a whole.

A small population size combined with rare breeding habitat that is prone to uncharacteristic wildfire makes the Pacific wren a candidate for species of conservation concern.

Red-faced warbler (*Cardellina rubrifrons*) is a regular breeder in deep, heavily forested canyons and in cool, steeply sloping drainages along the Mogollon Rim and high elevation mountains on the Tonto National Forest. Ecological conditions typically found in these breeding areas include vegetative communities of Douglas fir, white fir, ponderosa pine, and an understory of Rocky Mountain maple, Gambel’s Oak, and other broadleaf trees or shrubs (Corman and Wise-Gervais 2005). This habitat description falls into the Ponderosa Pine – Evergreen Oak and Mixed Conifer – Frequent Fire ecological response units, which are currently undergoing moderate and high departure, respectively.

Population trends for this species are unknown but thought to be declining (BirdLife International 2016). Threats to the persistence of red-faced warblers in the plan area include habitat loss and degradation from timber harvesting activity and wildfires (Corman and Wise-Gervais 2005). Timber harvesting appears to be a major influence on the presence of nesting red-faced warblers. One study found their numbers diminish greatly or vanish altogether with the presence of logging on their breeding grounds (Franzreb 1997).

The combination of declining population size, departed breeding habitat, and its preference for undisturbed areas make the red-faced warbler a candidate for species of conservation concern.

Sulphur-bellied flycatchers (*Myiodynastes luteiventris*) breed in the sycamore-lined drainages along the Mogollon Rim and other high elevation mountains on the Tonto National Forest (Corman and Wise-Gervais 2005). These breeding populations are separated by quite some distance, likely making them isolated from one another.

The ecological conditions necessary for the species include drainages with tall, broadleaf riparian woodlands, which translate to the Tonto National Forest’s Cottonwood Group riparian ecological response unit. The Cottonwood Group ecological response unit is not well represented on the Tonto. It is currently undergoing high departure and is projected over the next 100 years to increase slightly in departure (from 68 to 69 percent). The fire regime condition class of the upland habitat adjacent to the Cottonwood Group ecological response unit is class III.

The sulphur-bellied flycatcher is an at-risk species on the Tonto National Forest due to the low population numbers, isolated breeding populations, current and future departure of the species' breeding habitat, and risk of fire extirpating the small, isolated populations on the Tonto.

Western grebe (*Aechmophorus occidentalis*) is a winter resident on the larger reservoirs of the Tonto National Forest. The only known regular breeding population of this species in central Arizona is at Roosevelt Lake (T. Corman, personal communication, July 28, 2016). Not much is known about the population trend of this recently recognized (in 1985) species.

The ecological conditions necessary for breeding include large areas of open water and emergent or flooded vegetation (cattails and bulrushes) for nest cover (Corman and Wise-Gervais 2005). The biggest threat to the Roosevelt Lake breeding population is the water level on Roosevelt Lake (T. Corman, personal communication, July 28, 2016). This species begins nesting around the same time the water levels are lowered on the lake. When this happens, the nest built in flooded vegetation is no longer flooded and the birds cannot access their nest. This reduces the likelihood of successfully raising offspring. This species is also more susceptible to human recreation activities on the lake (Corman and Wise-Gervais 2005).

Western grebes are highly social on their breeding grounds, nesting in high-density colonies. If the population declines too much, the colony may become too small for them to colonially nest at the lake. This species should be considered at-risk over the long term on the Tonto National Forest due to their limited breeding range, conflicts with humans, and the water level of Roosevelt Lake.

Yellow-eyed juncos (*Junco phaeonotus*) reach the northern limit of their range on the Tonto National Forest. Currently there is one population of this Mexican species on the Tonto National Forest, located in the Pinal Mountain range. The necessary ecological conditions for the species in that mountain range includes forests containing Douglas fir, white fir, ponderosa pine, and oaks. In addition, the species requires forests that are cooler, wetter, and more shaded, while also requiring groundcover that consists of scattered grass clumps, small shrubs, forbs, ferns, downed trees, and an abundance of leaf litter (Corman and Wise-Gervais 2005).

The preferred habitat falls into the Madrean Encinal Woodland and Mixed Conifer - Frequent Fire ecological response units. These ecological response units are currently departed and expected to continue to be departed in the 100-year projection. The moderate to high departure of vegetative groundcover these ecological response units are experiencing is not beneficial for a junco that forages on the ground. The biggest threat to this species persisting long term on the Tonto National Forest is wildfire. A large wildfire in the Pinal Mountains could greatly reduce the population size and reduce the already limited habitat (about 5 percent of the total acreage on the Tonto National Forest) upon which the junco relies.

If this population is reduced or extirpated from the Pinal Mountains, it is unlikely the species would repopulate that mountain range due to the species' altitudinal migrations and few vagrant records of this species (eBird 2016). Given the junco's small, isolated breeding population and the increased wildfire risk due to wildfire suppression, this species should be considered at-risk on the Tonto National Forest.

Fish

Gila longfin dace (*Agosia chrysogaster chrysogaster*): Populations of Gila longfin dace show a declining trend in their current range (AGFD 2013). Populations are losing connection due to the loss of mainstem populations. The NatureServe conservation status is G4, S3S4 (globally apparently secure but vulnerable-secure at the state level) but needs to be re-evaluated due to the downward trend (NatureServe 2015). The species is a Tier 1B species of greatest conservation need in the State of Arizona (AGFD 2012).

Longfin dace are broad ranging in the lower Colorado River drainage but are rarely abundant in larger streams or at elevations above 5,000 feet. It is endemic to the Gila River drainage in the Tonto National Forest and is currently found in the middle Gila Subbasin, Upper Salt, Lower Verde, Lower Salt, and Tonto Basin local zones in the planning context area of the Tonto (AGFD 2013a).

Longfin dace are found in shallower waters (less than 0.6 feet) of small to medium-sized streams with sand or gravel substrates. This species has a tendency to remain in open, shallow areas throughout much of the day and to congregate in shaded, deep areas when water temperatures exceed 75 degrees Fahrenheit. Longfin dace are generally tolerant of high temperatures and low dissolved oxygen levels. Spawning occurs from December through July, and perhaps to September. Longfin dace use depressions in sandy bottom streams as redds, and redds are located along shorelines and on sandbars at depths of less than 0.6 feet.

The species is declining throughout the Tonto National Forest, having already disappeared from the mainstem Gila River entirely due to predation from introduced species. Changes in the hydrologic regime due to water withdrawals and impoundments have also fragmented and isolated populations of this species. Although the NatureServe S-rank has been left at an S3S4, it has not been updated since 2008 and is in need of evaluation due to continuing documented population decline and increasing threats of habitat loss from climate change (AGFD 2013a). Management actions that could improve conditions for Gila longfin dace include working in partnerships with Arizona Game and Fish Department personnel to remove invasive species and install migration barriers to protect native fish habitats. Additionally, actions that can attenuate habitat loss trends include acquisition of water rights on National Forest System lands and implementing best management practices to improve watershed function. Vegetation treatments that reduce fire intensity and magnitude will also promote watershed resilience under changing climate conditions.

This species is at high risk of continued habitat loss on the Tonto. Watershed condition is moderate to highly departed where this species is found: Upper Salt (97.8 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired); Lower Salt (75 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired); Lower Verde (67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired); Middle Gila (100 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired). All five watersheds are considered highly departed from reference for perennial stream miles containing nonnative species.

Invertebrates

Parker's cyllopeus riffle beetle (*Cylloepue parkerie*) is only know to occur in in spring-fed Roundtree Canyon and in Tangle Creek, in Bloody Basin in the Tonto National Forest. (R. Johnson 1992). NatureServe's rounded global status for Parker's cyllopeus riffle beetle is G1 (critically imperiled) and state status in Arizona is S1 (critically imperiled) due to its reduced abundance and distribution (NatureServe 2015).

This species in adult stage is a very small, black (sometimes with large reddish spots on the two wing cases), nonswimming beetle living on rocks, sand, and gravel in riffles. Both adults and larvae feed on periphyton, algae, moss, and vegetable material and inhabit permanent, clean, slow-moving, small streams with loose gravelly substrate and very little sand (AGFD 2003b). This species requires water with a high oxygen content and is highly sensitivity to pollutants. These factors greatly restrict distribution.

Threats to this endemic species are known to occur at only one spring; therefore, drought, wildfire, and overgrazing could cause the collapse of this species in the planning unit. Additional threats include development within and outside the Tonto National Forest boundary that result in groundwater depletion. In combination with climate change impacts that alter riparian areas, groundwater depletion can lead to reductions in streamflow and changes in water quality. Management activities that could improve habitat conditions for this beetle include implementing best management practices on projects in known occupied watersheds to reduce or eliminate factors that affect water quality and quantity such as grazing, mining, catastrophic fire, and dispersed recreational activities in riparian zones.

Parker's cyllopeus riffle beetle is narrowly endemic and is therefore at high risk for extirpation with habitat declines. Watersheds in the Lower Verde zone with perennial streams have moderate to high departure from reference condition; 67.5 percent of 6^{th}-level hydrologic unit code watersheds are functioning at risk or impaired.

Phoenix talussnail (*Sonorella Allynsmithi*) is a small (13 millimeter) terrestrial snail endemic to north-facing talus slopes along mountains near metropolitan Phoenix including North Phoenix, Scottsdale, Fountain Hills, Glendale, Peoria, Cave Creek, Carefree, and New River (Sorensen 2016; Waters 2011).

Although not associated with a forest ecological response unit (as it is endemic to talus slopes), it is found on slopes in the Sonoran Mid Elevation Desert Scrub (54 percent departed from reference conditions) and Sonoran Paloverde Mixed Cactus Desert Scrub (9 percent departed from reference conditions) ecological response units. These ecological response units are currently at low to moderate departure from reference conditions.

The species is susceptible to conditions that result in loss of soil moisture such as persistent drought and wildfire. Changes in vegetation leading to increased fire regimes are a threat for this species, as are urban development and material mining that remove rock habitats and compress interstitial spaces. Because of the small distribution, proximity to urban developed areas, and the high potential for invasive weed and wildfire pressures, this species is likely at moderate to high risk of habitat loss (Waters 2011). Activities that can reduce habitat loss and support viability of this species include recreation planning that reduces impacts from trail use and development in these sensitive areas. Additionally, vegetation management for assemblages that are resilient to catastrophic fires that create long-term damage to habitats would reduce risk of habitat loss for Phoenix talussnail.

Fossil springsnail (*Pyrgulopsis simplex)* is a hydrobiid class of snail. NatureServe's rounded global status for this snail is G1 and State of Arizona ranking is S1 (critically imperiled) because the species is known only from a spring near Strawberry, Gila County, along with Fossil Springs, Yavapai County, Arizona (NatureServe 2015). The species is presently listed as sensitive on the Region 3 forester's list (USDA Forest Service, 2013) and listed as Tier 1A species of greatest conservation need in Arizona (AGFD 2012).

Fossil Creek is a designated botanical conservation area and is protected from development with limited access to the area. Snails are typically found on rock or macrophytes and cannot withstand desiccation. Threats to this species include loss or degradation of aquatic habitats due to water development activities, loss of streamside vegetation, and increased sedimentation due to land management activities. Forest management activities that have contributed to habitat degradation include road construction and maintenance, timber management, fire suppression and subsequent stand-replacing fires, and permitted livestock grazing. Management needs include protection of spring source, and periodic monitoring of populations and their habitats (AGFD 2003, Stevens et al. 2014).

This species is a moderate risk of habitat loss due to loss of spring waters that provide the perennial flow to the creek (AGFD 2003c). In the Lower Verde zone, watersheds with perennial streams have moderate to high departure from reference condition with 67.5 percent of 6^{th}-level hydrologic unit code watersheds functioning at risk or impaired.

Monarch butterfly (*Danaus plexippus* pop. 1): This portion of the North American monarch population overwinters along the west coast, largely in California. The summer breeding range includes interior California, Nevada, Arizona, Utah, Idaho, Oregon, and Washington (NatureServe 2016). While considered a distinct population, these western monarchs regularly mix with eastern varieties. The Tonto National Forest falls in the spring and summer breeding habitat and may provide winter habitat for some small groups of monarch butterflies. Overwintering groups have been identified in Phoenix and along the Salt River (Morris and others 2015), which runs through the planning area.

In Arizona, monarchs can be found at various elevations year round. They often favor riparian areas and rivers where they use native species of milkweed (Morris and others 2015). Breeding and migrating butterflies have been found frequently in backyards and parks where they find nectar and milkweed. In years with mild winters and no hard freeze, the lower-elevation deserts have been found to provide overwintering habitat for small groups of monarchs.

Monarchs may be associated with most or all ecological response units in the planning area at different times of the year. However, riparian areas seem to be favored frequently in Arizona. Generally, this specialist is not closely tied to the departure of various ecological response units but instead closely follows the availability and condition of milkweed.

The population of western monarchs has declined by approximately 50 percent since the 1990 (NatureServe 2016). While much of the decline has been noted at overwintering sites on the West Coast (74 percent decline in less than 20 years), the primary threats appear to center on problems with breeding habitats. The primary threat is the loss of milkweed habitat associated with widespread herbicide use, pesticides, climate change, and land development (Xerces Society for Invertebrate Conservation 2016). While trends in milkweed habitat have not been studied in the planning area, the general trend in butterfly population suggests declines in monarch numbers will continue unless restoration efforts are conducted regionally. At present, milkweed restoration projects have been conducted on the Tonto National Forest in the Mesa Ranger District. The Tonto National Forest works to educate the public on monarch conservation and encourage involvement in restorations efforts.

The long-term population decline and continued threats indicate a substantial risk to the persistence of this species in the planning area.

Mammals

Allen's big-eared bats (*Idionycteris phyllotis*) have been found in a variety of habitats in Arizona, including ponderosa pine, pinyon-juniper, madrean woodland, white fir forest, and

Mohave Desert scrub. The bats are found in extreme southern Nevada, the southern third of Utah, throughout Arizona, the southwestern quarter of New Mexico, and south through the interior of Mexico (O'Shea and Bogan 2003). While surveys in the planning unit are limited and anecdotal, a few Allen's big-eared bats have been positively identified on the Tonto.

Allen's big-eared bats are often associated with water for feeding and drinking. They are most often encountered in ponderosa pine, pinyon-juniper, pine-oak woodland, and riparian habitats above 3,000 feet. Colonies are most often found in rocky places near riparian habitat or woodlands and the bats frequently use mine tunnels for roosting. Maternity colonies of 30 to 150 individuals have been found in mine shafts, boulder piles, lava beds, and beneath the loose bark of large ponderosa pine snags. These bats feed on moths, soldier beetles, dung beetles, leaf beetles, roaches, and flying ants by either catching them in flight or gleaning them from foliage.

A recent study in southern Nevada indicated a decline in the species. While this particular decline could be related to a 5-year drought, overall anecdotal information indicates this species is severely declining (NDOW.org 2006).

Information on the condition of natural cave habitat features is not known in the planning unit; however, vandalism in caves, closures of man-made habitat (that is, mines), and loss of old snags may threaten maternity roosts.

These bats are most commonly associated with Cottonwood Riparian ecological response units. Overall cottonwood riparian areas are impaired due to hydrologic changes resulting a decline of pulsing floods that help establish sediment terraces and provide a base for seed regeneration. As a result, these areas are transitioning to single-age, older cottonwood galleries with little to no regeneration. In addition, the 6^{th}-level hydrologic unit code watersheds (Upper Salt, Lower Salt, Lower Verde, Middle Gila, and Tonto Basin) are functioning at risk or impaired greater than 65 percent, depending on the watershed.

Stressors on water resources, including drought, fire, and an increased demand for water, are expected to continue into the future. Threats include development within and outside the Tonto National Forest boundary resulting in groundwater depletion. These stressors are difficult to quantify but likely will result in further declines in overall availability and quality of riparian habitat and riparian insect diversity and density, which is a main food source for these bats. Due to the moderate to high percentage from departure of riparian ecological response units and subwatersheds across the Tonto, threat to this species' persistence is considered high.

California leaf-nosed bat *(Macrotus californicus*): While no large roost sites are known to be located on the Tonto and survey records for this species are limited, the species has been recorded on the Tonto National Forest (NatureServe). California leaf-nosed bats do not migrate or hibernate but instead form a small number of large colonies. The bats are restricted to a specific roost requirement (temperature) with roosting colonies found in caves or mines that maintain a warm temperature greater than 28 degrees Celsius, often due to geothermal heat.

Foraging occurs in dry areas 3 to 6 miles from roosts, often in desert washes. This species is most likely associated with the Desert Willow riparian ecological response unit, which represents 11 percent of riparian ecological response units in the planning unit. Most streams assessed in ecological response units were rated unstable; however, large portions of this ecological response unit are located in desert washes, which are naturally unstable. Current departure for the Desert Willow riparian ecological response unit is considered low, but the projected 100-year departure is considered high, in part due to the expansion of red brome. Brome grasses provide the fine fuels that carry desert fires. Conditions such as drought, followed by exceptionally wet winter and spring, can create a landscape undesirable for this ecological response unit.

For the foreseeable future, foraging areas for this species are expected to be at high risk. Due to the limited and specific requirements for roosting colonies and the threat to riparian foraging habitat, the threat to this species' persistence in the planning area is considered high (O'Shea and Bogan 2003).

Western red bat (*Lasiurus blossevillii*): While surveys within the planning unit are limited, the western red bat has been detected in the planning area. These bats are solitary animals who prefer riparian areas dominated by walnuts, oaks, willows, cottonwoods, and sycamores to roost in the tree foliage. Favored roosts are where trees have a dense canopy above and branches do not obstruct the bat's flyway below.

Though decline of the western red bat is not documented within the planning unit, they appear to have declined markedly in the west. The decline is attributed to the loss of lowland riparian forests due to a lack of regeneration from hydrological alteration of watersheds (O'Shea and Bogan 2003). These bats are associated with the Cottonwood Riparian ecological response unit, which is currently rated as having impaired function. Hydrologic changes have decreased pulsing floods that help establish sediment terraces and provide a base for seed regeneration. As a result, cottonwood riparian areas are becoming single-age, older cottonwood galleries with little to no regeneration. There has been a sharp decline in cottonwoods in the reservoir systems in the planning unit due to the change in hydrologic regime where periodic flushing on rivers and streams is impeded by dams.

In addition, the 6th-level hydrologic unit code watersheds (Upper Salt, Lower Salt, Lower Verde, Middle Gila, and Tonto Basin) are functioning at risk or impaired greater than 65 percent, depending on the watershed. Stressors on water resources, including drought, fire, and an increased demand for water, are expected to continue into the future. Threats include development within and outside the Tonto National Forest boundary resulting in groundwater depletion. Overall these stressors are difficult to quantify but likely will result in further declines in availability and quality of riparian habitat and in the riparian insect diversity and density, which is a main food source for these bats. Due to the moderate to high percentage from departure of riparian ecological response units and subwatersheds across the Tonto, threat to this species' persistence is considered high.

Plants

Alamos deer vetch (*Lotus alamosanus*) is a semi-aquatic perennial herb known from only one site on the Tonto National Forest (Lower Salt local zone) which represents the only occurrence in Arizona. This site is disjunct from the California and Mexico populations. While the entire species range is unclear, the largely separated site on the Tonto (from known herbaria records and observations) from the main distribution may represent important genetic material for the species (genetic cline). The plants require wet soils and can be found at springs, seeps, and perennial streams of canyons and meadows (NatureServe 2016).

Alamos deer vetch is found at riparian areas in the Mojave Sonoran Desert Scrub ecological response units on the Tonto. While little is known about threats for the species, desert perennial riparian areas are sensitive to overuse (high recreational impacts) and water withdrawals that can greatly reduce or eliminate populations. Additionally, almost half of sampled riparian streams in the Lower Salt local zone are rated unstable and 32 percent are rated impaired. These desert riparian ecosystems are at high risk and conditions are projected to worsen from drying conditions (climate change and drought), increasing water demands (surface and subsurface flows) and heavy use (recreation).

This species is carried forward as a potential species of conservation concern because, without effective management direction for this species, current and foreseeable stressors are likely to result in a significant loss of habitat and its potential extirpation at the only known locality on the Tonto. Also, key risk viability factors, including the extremely small population size, current and projected status of the habitat, and multiple stressors from recreation and water withdrawals, are of sufficient magnitude to warrant concern for the species' persistence on the Tonto National Forest over the long term.

Aravaipa sage (*Salvia amissa*) is a perennial, riparian obligate species. The leaf shape, leaf hairs, and elevation distinguish *S. amissa* from the other 14 *Salvia* species in Arizona. Aravaipa sage is known from five sites on the Tonto National Forest in the Lower Salt and Upper Salt (Sierra Ancha Mountains) zones. Some suspect the species to be extirpated at the Superstition Mountains in the Lower Salt zone (Gori 1999 in AGFD 2002). Plants are restricted to wetlands and riparian areas and are found at upper alluvial terraces in shady canyon bottoms, along streambanks, and in cienega-like graminoid and herb communities (AGFD 2002, SEINet 2016). Plants are also under the canopies of mature sycamore (*Platanus wrightii*), walnut (*Juglands major*), ash (*Fraxinus velutina*) and mesquite (*Prosopis* sp.). Population sizes are cited as locally abundant where found (AGFD 2002). However, plants are rarely found in suitable or potential habitat (Warren 1994).

On the Tonto, sites are associated with the Cottonwood riparian ecological response unit. Adjacent plant communities include Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire (Sierra Ancha Mountains) ecological response units. Fifty percent of the streams assessed in the Cottonwood riparian ecological response unit are rated as impaired, with another 33 percent rated as unstable. Plant surface roots anchor and stabilize soils. Current conditions shows a substantial loss in surface roots indicating a potential loss in streambank stability at sites (reference "Riparian" section). While fires generally do not occur in the riparian corridor, areas with high fuel loads and located adjacent to rivers can increase fire spread and severity in the riparian zone (specifically when sites are experiencing drought).

Current conditions show high fuel loads in the adjacent plant communities and surrounding watershed, increasing the risk of wildfire and subsequent soil loss (from heating), runoff, sedimentation, and increased flooding. The few sites on the Tonto (four reliably documented) and degraded habitat conditions raise substantial concern for the species' persistence on the Tonto National Forest.

Arizona bugbane (*Cimicifuga arizonica*) is a perennial herb with populations known from the Mogollon Rim with disjunct sites at the Bill Williams Mountain in Coconino County and the Sierra Ancha Mountains (Tonto National Forest) in Gila County. Arizona bugbane is associated with the Ponderosa Pine/Willow and Cottonwood riparian ecological response units on the Tonto. Adjacent upland communities include Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units. Plants are associated with particular habitat conditions: slopes greater than 30 degrees with little to no direct sun, north aspects with deep to rich saturated soils where waterfalls and weeping cliffs drip onto individuals. These conditions are considered rare compared to the other known Arizona bugbane sites in the state and uncommon on the Tonto National Forest (Rink 2016).

The most noted direct threats on the Tonto come from recreation with numerous minor accounts documented (Gobar 1990, Lutch 1998, Philips 1982, Warren 1991). Also, changes in humidity, water quality, streamflow, and canopy cover could severely affect populations (U.S. Fish and Wildlife Service 1989, Philips 1984). Over 50 percent of the streams in both the Cottonwood and Ponderosa Pine/Willow ecological response units are rated as impaired. Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units are highly departed across the Tonto National Forest with the highest departure at the Upper Salt and Tonto Basin zones. All known populations and potential habitat are located in these local zones.

Current conditions show high fuel loads in both Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units. Projections show slight improvement, specifically in the Ponderosa Pine - Evergreen Oak ecological response unit, but overall habitat conditions remain moderately departed. High fuel loads increase the risk of wildfire and subsequent soil loss (from heating), runoff, sedimentation, and flood scouring at nearby riparian areas. While recent findings suggest plants may be adapted to more frequent disturbance (reestablishing from buried rhizomes) than previously thought (Rink et al. 2015), population renewal tends to occur more from the seed banks than surviving individuals (Ayre et al. 2009). Also, increased flooding may eliminate upstream propagule sources and reduce the seed bank and genetic diversity of downstream populations over time. It is unclear what other negative impacts) may have on Arizona bugbane populations; for example, increased flooding from wildfire, soil heating, altered microsite conditions, and reduced canopy cover.

A number of factors including the limited range, few sites, large distances between sites (disjunct), rarity of habitat conditions, and the highly departed habitat pose significant threats for sites to sustain viable Arizona bugbane populations on the Tonto National Forest. Arizona bugbane is currently protected under candidate conservation agreement signed in 1999.

Arizona giant sedge (*Carex ultra*) is known from only two sites in the Lower Verde zone on the Tonto National Forest (SEINet 2015). Plants are found near perennial streams, wet springs, and streams in the Cottonwood Riparian ecological response unit (AGFD 2000). The adjacent plant communities include the Pinyon-Juniper Woodlands ecological response unit. The isolated nature of populations and restricted habitat features (wet soils near perennial streams) on the Tonto make this species particularly vulnerable. Fifty percent of the streams assessed in the Cottonwood riparian ecological response unit are rated as impaired, with another 33 percent rated as unstable.

Plant surface roots anchor and stabilize soils. Current conditions shows a substantial loss in surface roots indicating a potential loss in streambank stability at sites (reference “Riparian” section). Soil condition is rated as unsatisfactory for the Cottonwood and Pinyon-Juniper Woodland ecological response units, resulting in a potential loss in soil function (plant-available moisture) and reduced site productivity. All known sites on the Tonto are along seeps and springs of the Verde River.

Competing demand for water is a growing concern as a result of the rapid population growth and development in the Prescott metropolitan area and Yavapai County (Roark 2016). The few sites on the Tonto, degraded habitat conditions, and foreseeable threats raise substantial concern for the species’ persistence on the Tonto National Forest.

Blumer’s dock (*Rumex orthoneurus*) is a long-lived, herbaceous perennial; Forest Service sensitive species; and designated as “highly safeguarded protected” under the Arizona Native Plant law (1993). On the Tonto National Forest in the Sierra Ancha Mountains, four natural populations have been documented but only three extant populations confirmed (Thompson and

Hodges 1996). In addition to the native populations, 17 transplanted populations were established along the Rim at the Tonto Basin and Upper Salt zone. Eight populations have been extirpated, one is potentially stable, and nine have experienced declines in the number of individuals (Thompson and Hodges 1996). Reasons for population declines on the Tonto include severe flooding following wildfires (Dude and Bray fires in 1990), grazing impacts, and insect herbivory (AGFD 2002, Thompson and Hodges 1996). Other negative impacts to populations on the Tonto include trampling (livestock, horses) and habitat degradation from road construction, water developments, and recreation-related activities such as camping and hiking (Thompson and Hodges 1996).

Blumer's dock occurs in riparian habitats at elevations between 4,480 and 9,660 feet (AGFD 2002). On the Tonto National Forest, the adjacent plant communities and ecological response units are Mixed Conifer - Frequent Fire and Ponderosa Pine - Evergreen Oak and the riparian ecological response units are Cottonwood and Ponderosa Pine/Willow. Key habitat features include moist loamy soils adjacent to springs, flowing streams in open meadows, and meadows with canopy cover. Plants can be found at the drier headwaters of some areas. They typically occur in open, sunny locations but can occupy more shaded sites. Suitable habitat makes up a small proportion of the Tonto (combined acreage for Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units is 9 percent).

Current conditions show high seral state departure for Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units through the Tonto National Forest. Ponderosa Pine - Evergreen Oak departure is the highest at the Upper Salt zone, where all natural populations are located (Sierra Ancha Mountains). Additionally, departure is moderate to high at introduced sites: Lower Verde and Tonto Basin zones. Both Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units have high fuel loads (coarse woody debris and high shrub densities) with a significant amount of acres in fire regime condition class III (greater than 40 percent for both ecological response units) indicating high departure in fire regime. High fuel loads increase the risk of wildfire and subsequent soil loss (from heating), runoff, sedimentation, and flood scouring at nearby riparian areas. These factors can greatly reduce or eliminate Blumer's dock populations. Fifty-one percent of the riparian streams on the Tonto National Forest are rated as impaired, with the highest ratings at the Upper Salt (62 percent impaired). Ponderosa Pine - Evergreen Oak and Mixed Conifer - Frequent Fire ecological response units will remain moderately departed. Projections show a large number of acres in closed-canopy states, increasing the risk of wildfire, insects, and disease.

Blumer's dock was proposed for Federal listing but withdrawn in 1999 because threats were deemed not sufficiently widespread across the species entire range. Populations on the Coronado and Tonto National Forests (implemented in 1993) are being monitored under a conservation strategy. When the species was proposed for listing it was only known from 10 sites in Arizona. Genetic work confirmed populations previously identified as *R. occidentalis* were in fact *R. orthoneurus*, confirming an additional 134 sites (excluding the introduced sites). Asexual reproduction through rhizomes results in low genetic diversity at sites, so preserving populations at distinct mountain ranges across the species' range is important to maximize the genetic variation and overall gene pool (Federal Register 64:125, August 9, 1999). The loss of populations on the Tonto National Forest (Sierra Ancha Mountains) could lower the viability of the species overall. A number of other factors, such as declining population numbers (specifically at introduction sites), few sites on the Tonto, degraded riparian habitat conditions and wildfire risk, pose significant threats to Blumer's dock.

Broadleaf lupine (*Lupinus latifolius* ssp. *leucanthus*) is a tall, herbaceous perennial distributed throughout central Arizona and southern Utah, and perhaps a disjunct population in New Mexico. Plants are known from two locations on the Tonto National Forest at the Lower Verde and Tonto Basin local zones. Plants are commonly found near perennial streams with adequate soil moisture most of the year and at dry streams with moist soils (Baker 2014, AGFD 2005). Current and potential habitat on the Tonto National Forest includes Pinyon-Juniper Woodland, Pinyon-Juniper Evergreen Shrub, Interior Chaparral, Ponderosa Pine Forest, and Mixed Conifer - Frequent Fire ecological response units. While not defined as a riparian obligate, threats include wetland degradation, severe flooding, drying soils, and weed infestations, specifically those with perennial rhizomes that displace native species (Baker 2014).

Potential threats also include collection due to the horticultural potential (splendid long racemes of large flowers). With the exception of the Interior Chaparral ecological response unit, current conditions show moderate to high seral state departure. Current conditions show high fuel loads (coarse woody debris and closed-canopy states) in the Ponderosa Pine - Evergreen Oak, Mixed Conifer - Frequent Fire, and Pinyon-Juniper Evergreen Shrub ecological response units. High fuel loads increase the risk of wildfire and subsequent soil loss (from heating), runoff, sedimentation, and increased flooding. These factors can significantly influence wetland and riparian degradation and subsequent habitat loss. Additionally, these ecological response units have high erosion hazards and a high risk of soil loss (reference “Soils” section).

Even though projections show some ecological response units trending towards reference conditions and reaching low departure (Interior Chaparral and Pinyon-Juniper Woodland), 57 percent of suitable habitat will remain moderately and highly departed (Pinyon-Juniper Evergreen Shrub, Ponderosa Pine Forest, and Mixed Conifer - Frequent Fire). For these reasons, there is substantial concern for broadleaf lupine persistence on the Tonto National Forest.

Davidson sage (*Salvia davidsonii*) is perennial herb only known from one site in the Lower Salt zone on the Tonto. Plants are found in rocky soils in canyons, and in rich, moist soils on wooded slopes, seepy detritus slopes, ledges and at terraces above stream channels (SEINet 2016). Only seven sites in Arizona (1 in New Mexico) have been seen since 1992 (NatureServe 2016). When the habitat is intact, plants are generally resistant to erosional disturbance due to the rocky substrate (NatureServe 2016). Plants have been documented along canyons on the Tonto in the Mojave Sonoran Desert Scrub ecological response unit. Threats and limiting factors for this species are not clearly understood; however, plants require moist soil conditions (AGFD 2002). Perennial streams in desert riparian areas are at risk from increasing water demands. Also, climate change impacts, such as increasing aridity in the Southwest, may reduce plant-available soil moisture (through a change precipitation regimes). For these reasons, there is substantial concern for the species’ persistence on the Tonto National Forest.

Fish Creek fleabane (*Erigeron piscaticus*). This species is an extremely rare annual only known from three localities: two in Arizona and one in Sonora, Mexico. Population sizes are very small, averaging less than 80 individuals (AGFD 2001, SEINet 2016). The current status of populations on the Tonto National Forest is unknown but the fleabane has been documented from the historical Fish Creek site in 1921 and 1931 at the Superstition Mountains (AGFD 2001). According to Dave Gori (1999), there are no extant populations in the state of Arizona except at Oak Grove Canyon (outside the Tonto National Forest). However plants are rare annuals. They may not emerge in some years; therefore, populations are assumed to be extant and not extirpated on the Tonto. Additionally, plants may require specific environmental conditions over periods of time to germinate and establish (AGFD 2001). Plants are found in riparian areas in woodlands and moist alluvium at shady canyon bottoms along perennial streams. Suitable habitat in the Superstition Mountains include the Cottonwood riparian ecological response unit and adjacent communities include Sonoran Desert Scrub, Interior Chaparral, and Semi-Desert Grassland ecological response units. Threats include poor watershed conditions, recreation (hiking traffic), and flooding (AGFD 2001, Interagency Sensitive Plant Assessment 2004). Fifty percent of the streams assessed in the Cottonwood riparian ecological response unit are rated as impaired, with another 33 percent rated as unstable.

Plant surface roots anchor and stabilize soils. Current conditions shows a substantial loss in surface roots indicating a potential loss in streambank stability (reference "Riparian" section). No surveys have been conducted to determine the extent of populations within suitable habitat on the Tonto National Forest. Therefore, the uncertainty (site on the Tonto not surveyed in over 25 years), the extreme rarity on and off the Tonto, and the degraded site conditions raise substantial concern for Fish Creek fleabane persistence.

Fish Creek rock daisy (*Perityle saxicola*) is an herbaceous perennial with an extremely limited distribution. The entire species range is on the Tonto National Forest at the Upper Salt zone, and all known sites are within 5 miles of each other (AGFD 2004, SEINet 2016). Plants are found on very steep slopes and in the cracks and crevices of cliff faces, large boulders, and rocky outcrops that occur in canyons with east and northeast exposures. Suitable habitat on the Tonto includes Sonoran Desert Scrub and Pinyon-Juniper Evergreen Shrub (Sierra Ancha Mountains) ecological response units. While suitable habitat makes up a significant proportion of the Tonto National Forest (combined ecological response unit acreage is 40 percent of the Tonto), plants are only known to occupy a very small proportion of the habitat.

Fire is most likely a low threat because the adjacent communities are predominately in the Sonoran Desert Scrub ecological response unit, and they lack the fuels capable of affecting plants at cliff faces. However, there are a few sites and moderate amount of potential habitat in the Pinyon-Juniper Evergreen Shrub ecological response unit. Wildfires in the Pinyon-Juniper Evergreen Shrub ecological response unit are more likely to produce hot fires capable of damaging individuals. Current condition shows high seral state departure in this ecological response unit. Fire suppression and grazing in this type have contributed to a lengthening of the fire return interval to 215 years instead of the 35 to 100 or more years found under reference conditions. This has allowed the coarse woody debris to build up to 23.9 tons per acre, changing the fire behavior to the point where wildfires are more resistant to control.

While some populations are less impacted by direct impacts from wildfire (plants at cliff faces), indirect effects from wildfires, such as intense heating, may damage individuals and alter local site conditions. While conditions are projected to improve, the Pinyon-Juniper Evergreen Shrub ecological response unit will still be moderately departed with 31 percent of acres in a closed-canopy state. Closed-canopy conditions increase stress and insect and pathogen outbreaks and change wildfire behavior. Additionally, while there is moderate uncertainty on the vulnerability of the Pinyon-Juniper Evergreen Shrub ecological response unit to climate change, juniper communities (Juniper Grass, Pinyon-Juniper Grass, Pinyon-Juniper Woodland) overall are highly vulnerable to climate change (reference "Climate Change" section). The limited range, along with the impaired habitat conditions over a moderate percent of the potential habitat (Sierra Ancha Mountains), make the Fish Creek rock daisy particularly vulnerable to extirpation on the Tonto National Forest.

Flagstaff beardtongue (*Penstemon nudiflorus*) is perennial herb endemic to Arizona (AGFD 2003) with 3 sites located on the Tonto in the Lower Verde zone. This plant is restricted to small, scattered limestone and sandstone outcrops of relatively undisturbed habitat at elevations ranging from 4,500 to 7,000 feet. Associated vegetation includes ponderosa pine, gambel oak, blue grama, and alligator juniper. Populations are not abundant for all known occurrences (AGFD 2003). Much of its habitat is grazed across its range (USDA Forest Service Region 3 sensitive plant list 2013). The species responds favorably to low-intensity fires (USDA Forest Service Region 3 sensitive plant list 2013). Populations are found within Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest ecological response units. These ecological response units show high departure for current and projected conditions. The largest risk to population on the Tonto National Forest is habitat loss from severe wildfires. For Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest ecological response units, the fire regime is highly departed with more high-severity fires occurring in across the landscape. For these reasons, there is substantial concern for Flagstaff beardtongue populations on the Tonto.

Gila rock daisy (*Perityle gilensis* var. *gilensis*) is a small perennial and one of the two varieties within *Perityle gilensis*. It is hypothesized that *P.* var. *gilensis* originated from *P.* var. *salensis* via migration down the Salt River Canyon and through the establishment of autopolyploidy (Powell 1973 in Lutch 2000). The Tonto National Forest represents the center of the species distribution and almost entire range of the species (SEINet 2016). The Gila rock daisy is narrowly distributed on the Tonto, present in the Upper Salt and Lower Salt zones. Suitable habitat includes cliff faces and rock outcrops in Sonoran Desert Scrub, Juniper Grass, Interior Chaparral, and occasionally Ponderosa Pine - Evergreen Oak ecological response units. The suitable habitat makes up a significant proportion of the Tonto, but plants do not fully occupy the habitat; they are restricted to cliff faces and rock outcrops. Plants are also found in small pockets of soil in vertical and near-vertical Rhyolite cliffs.

Mentioned threats to the species include dam building and reservoir expansion. While there are currently no plans to expand reservoirs on the Tonto National Forest, future developments can potentially eliminate populations. Also the limited range and negative impacts from potential mining raise concern for the species' persistence (Interagency Sensitive Plant Assessment 2004).

Fire is most likely a low threat given the adjacent communities are predominately the Sonoran Desert Scrub ecological response unit and they lack the fuels capable of affecting plants at cliff faces. However, 4 out of 10 sites are located in Juniper Grass, Interior Chaparral, and Ponderosa Pine - Evergreen Oak ecological response units which are capable of producing hot fires. While direct negative impacts from fires are low, intense heating from severe fires may damage individuals and alter local site conditions. Current conditions show moderate to high departure in Juniper Grass and Ponderosa Pine - Evergreen Oak ecological response units, respectively. Both have excess coarse woody debris, large patch sizes, and a loss of effective vegetative groundcover capable of carrying nonlethal surface fires. As a result, fire return intervals are much longer and fires are burning at mixed to high severities, deviating away from reference conditions of frequent, low to mixed-severity fires. While the Juniper Grass ecological response unit is projected to reach low seral state departure, 34 percent will still remain in a denser state in the future, rendering it susceptible to outbreaks of insects, pathogens, and stand-replacing wildfire. For these reasons, there is substantial concern for the Gila rock daisy on the Tonto National Forest.

Grand Canyon century plant (*Agave phillipsiana*): This agave species occurs on pre-Columbian agricultural sites on sandy, gravelly, and rocky soils along hillsides, slopes, and ridgelines. On the Tonto National Forest, populations are found only in the Tonto Basin local zone at the foothills of the Sierra Ancha Mountains. Plants are often found near permanent water sources (Hodgson et al. 2003). Associated community types include Mojave Sonoran Desert Scrub, Semi-Desert Grassland, and Juniper Grass ecological response units. Similar to other agaves, Grand Canyon century plant reproduction is known primarily from clonal offshoots.

Documented threats include hiker activity and fires from campsites (Hodgson 2001). Grand Canyon century plant does not react well to fire (W. Hodgson and A. Salywon, personal communication, 2016). Fire damage to individuals may occur where vegetation is dense. While current conditions show an overall low departure (seral state) for Mojave Sonoran Desert Scrub ecological response unit, 55 percent of the acres are in fire regime condition class III, indicating high departure in fire regime. Increased shrub densities and exotic grasses at sites have altered the fire regime (increased fire frequency and severity) in the Mojave Sonoran Desert Scrub ecological response unit. This ecological response unit is projected to trend away from reference conditions, resulting in decreased cacti, shrub, and tree cover and an increase in exotic grass cover (increasing the risk of uncharacteristic fire).

Agave roots are shallow and spread outward to capitalize on moisture in the upper soil layers. While direct damage to individuals from recreation (such as off-highway vehicle use) is low, soil compaction at sites may reduce plant-available moisture. A loss of soil productivity and function is already evident; current conditions show nearly 50 percent of Mojave Sonoran Desert Scrub soils are rated as impaired. The few known localities (only one site documented on the Tonto), degraded habitat conditions, and limited reproductive potential increase the likelihood of extirpation of Grand Canyon century plant on the Tonto National Forest.

Hodgson’s fleabane (*Erigeron hodgsoniae*) is a recently described species with the entire range known only from only four collections at the Sierra Ancha Mountains (Upper Salt zone), all less than 0.5 miles from each other (Nesom 2015, SEINet 2016). Hodgson’s fleabane is sympatric with the Sierra Ancha fleabane (*E. anchana*) found at granite cliff faces, steep walls, at and above waterfalls, in partially shaded habitat and at the bottom of canyons in Ponderosa Pine - Evergreen Oak and potentially Pinyon-Juniper Evergreen Shrub and Interior Chaparral ecological response units on the Tonto National Forest.

While potential direct threats are low (the species inhabits rock crevices and rock faces), current conditions show high fuel loads from the accumulation of coarse woody debris and closed-canopy conditions are capable of producing very hot fires. Additionally, the highest departure for the Ponderosa Pine - Evergreen Oak ecological response unit is at the Upper Salt zone where all populations are located. While the effects of fire are unknown for Hodgson’s fleabane, intense heating can potentially damage individuals and alter habitat microclimate.The Pinyon-Juniper Evergreen Shrub ecological response unit is projected to trend towards reference conditions but will still remain departed after 100 years, with 31 percent of the acres in closed-canopy states, increasing the risk of wildfire. Additionally, pinyon-juniper habitats are at significant risk of increased drying, stress, and prolonged drought from climate change. Seventy-seven percent of the Pinyon-Juniper Evergreen Shrub ecological response unit on the Tonto is assessed to have moderate to high vulnerability to climate change. The Tonto National Forest has a significant influence on the viability of the species because the entire range is located on the Tonto. While direct impacts are low, current and projected conditions show the habitat trending away from reference conditions. For these reasons, there is substantial concern for Hodgson’s fleabane persistence on the Tonto National Forest.

Hohokam agave (*Agave murpheyi*) is a perennial succulent usually found on benches or alluvial terraces on gentle bajada slopes (not steep slopes or drainage bottoms) above major drainages in the Mojave Sonoran Desert Scrub ecological response unit. The species is associated with pre-

Columbian agricultural and settlement features (cultivated by the Hohokam). Murphey's agave is found in all local zones on the Tonto but not at high densities (SEINet 2016). Population sizes are relatively small, with each distinct population having fewer than 50 individuals (NatureServe 2016). Recent population declines have been observed at a number of sites (W. Hodgson and A. Salywon, personal communication, 2016). As with most agaves, Hohokam agave is probably self-incompatible requiring outcrossing, with the primary mode of reproduction being vegetative through rhizomatous offsets called pups (AGFD 2003). Few, if any, seeds develop; they are aborted soon after flowers develop (AGFD 2003).

While habitat loss from urban sprawl and development poses the highest threat to Hohokam agave, fires may increase habitat loss where vegetation is dense. While current conditions show an overall low departure (seral state) for the Mojave Sonoran Desert Scrub ecological response unit, fifty-five percent of the acres are in fire regime condition class III, indicating high departure in fire regime. Increased shrub densities and exotic grasses at sites have contributed to the altered fire regime (increasing the risk of fire frequency and severity) in the Mojave Sonoran Desert Scrub ecological response unit. This ecological response unit is projected to trend away from reference conditions resulting in decreased cacti, shrub, and tree cover and an increase in exotic grass cover (increasing the risk of uncharacteristic fire).

The reconstruction of the Roosevelt Dam and expansion of Roosevelt Lake resulted in the elimination of a Hohokam agave clone (AGFD 2003). While there are currently no plans to expand any reservoirs on the Tonto National Forest, future developments can potentially eliminate populations.

Agave roots are shallow and spread outward to capitalize on moisture in the upper soil layers. While direct damage to individuals from recreation (such as off-highway vehicle use) is low, soil compaction at sites may reduce plant-available moisture. As with most agaves, Hohokam agave is susceptible to root rot and requires well-drained soils (AGFD 2003). A loss of soil productivity and function is already evident; current conditions show nearly 50 percent of Mojave Sonoran Desert Scrub soils are rated as impaired.

Habitat alterations, such as the removal of rock piles can also negatively impact species as rocks discourage rodents and help accumulate nutrients and water. In addition to the departed habitat conditions on the Tonto, another potential threat is illegal collection for cultivation and products. These factors, along with the small population sizes and limited reproductive potential, increase the likelihood of local extinction or extirpation of Hohokam agave on the Tonto National Forest.

Horseshoe deer vetch (*Lotus mearnsii* var. *equisolensis*). This species is extremely restricted. The only known population for the state of Arizona is located on the Tonto National Forest, covering 2.2 square kilometers; it is of very high conservation concern (Arizona Rare Plant Assessment 2014). Plants are found growing on calcareous soils in the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit and potential habitat includes the Sonoran Desert Scrub ecological response unit.

While current conditions show low seral state departure for the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit, habitat degradation is apparent. More than 80 percent of soils in Sonora-Mohave Mixed Salt Desert Scrub are rated as impaired to unsatisfactory. Nearly 50 percent of soils in the Sonoran Desert Scrub ecological response unit are impaired. Impaired and unsatisfactory soils can result in unstable soils with reduced hydrological function and nutrient cycling.

Direct threats to the species are unknown; however, the habitat is highly susceptible to negative impacts from the expansion of reservoirs and off-road vehicle use. Limited distribution, uncertainty about the extent of suitable habitat (no surveys conducted), and degraded habitat conditions raise substantial concern for horsehoe deer vetch persistence on the Tonto National Forest.

James' rubberweed (*Hymenoxys jamesii*) is an Arizona endemic with the majority of the range restricted to the Mogollon Plateau of eastern central Arizona (SEINet 2016). This species is ranked vulnerable to imperiled at both global (G) and local scales (S) on NatureServe. Populations on the Tonto represent the southern edge of the species distribution. Known from one location on the Tonto at the Lower Verde zone, plants are found in the Ponderosa Pine - Evergreen Oak ecological response unit. Little information is available on life history and population status (NatureServe 2016). However, much of the habitat is highly departed, with the largest threat to habitat loss coming from catastrophic fires.

High stand densities and excess amounts of coarse woody debris are increasing the risk of severe wildfires and potential habitat loss for James' rubberweed populations on the Tonto. The Ponderosa Pine - Evergreen Oak ecological response unit has high fuel loads (coarse woody debris and high shrub densities) with a significant amount of acres in fire regime condition class III indicating high departure in fire regime. High fuel loads increase the risk of wildfire and subsequent soil loss (from heating), runoff, sedimentation, and flood scouring at nearby riparian areas. These factors, along with the limited distribution and single known site on the Tonto, raise substantial concern for the species' persistence.

Mapleleaf false snapdragon (*Mabrya acerifolia*) is a perennial vine. It is the only species in the Genus *Mabrya* and may be a paleoendemic (Arizona Rare Plant Assessment 2014). The species range is very small, with a majority of the habitat on the Tonto National Forest (SEINet 2015). This prostrate, mat-forming plant is found at rock overhangs, on shaded cliffs, rock ledges, and Rhyolite rock crevices at north- to east-facing canyon walls. Mapleleaf false snapdragon is narrowly distributed on the Tonto National Forest, with all sites located in the Lower Salt zone. The Sonoran Desert Scrub ecological response unit makes up a moderate amount of suitable habitat on the Tonto (22 percent), but plants occupy a relatively small proportion of the suitable habitat because they are restricted to specific habitat features – rock crevices and cliff faces.

Future projects in the Salt River Canyon and Superstitions (such as trail construction and dam construction) may negatively impact the species (Lutch 2000). Also the extremely limited range and negative impacts from potential mining raise concern for the species' persistence (Interagency Sensitive Plant Assessment 2004). Current conditions show low seral state departure in the Sonoran Desert Scrub ecological response unit, with projections showing high seral departure (100-year projection). Plants are probably less influenced by the conditions of the associated habitat and more impacted by other factors such as habitat loss from mining, recreational activities (trail construction) and dam building.

Many cliff dwelling ecosystems harbor a number of rare and uniquely adapted species that contribute greatly to regional biodiversity (Larson et al. 2000). Recreational activity (rock climbing) within these ecosystems can reduce plant size, vigor, and genetic diversity (Volger and Reish 2011). While there is currently no information on whether cliff climbing is impacting species on the Tonto National Forest, a number of sites are close (Superstition Mountains) to the Phoenix metropolitan area. The Tonto experiences high recreational impacts, and recreation is expected to increase with increasing population growth and urban expansion. For these reasons, there is substantial concern for the viability of Mapleleaf false snapdragon on the Tonto National Forest.

Metcalfe's tick-trefoil (*Desmodium metcalfei*) is sparsely distributed in New Mexico, Arizona, and Mexico. In Arizona, 3 out of the 12 sites are located on the Tonto (SEINet 2016). This species is known from 3 sites on the Tonto at the Tonto Basin, Lower Verde, and Lower Salt zones. This rare perennial species is found near wetlands (cienega-like habitats) and in the shade of riparian areas on the Tonto (SEINet 2016). Current and potential habitat include Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest, Mixed Conifer - Frequent Fire, Pinyon-Juniper Grass, and Semi-Desert Grassland ecological response units. Plants may also be found at rocky slopes, canyons, ditches, and washes in the Mojave Sonoran Desert Scrub ecological response unit. This species is noted as being very palatable and is common in grazed community types (USDA Forest Service Region 3 sensitive plant list 2013).

On the Tonto, impacts from grazing are unknown. Risk to habitat loss from catastrophic fires, from high stand densities and excess coarse woody debris, is high in the Ponderosa Pine - Evergreen Oak, Ponderosa Pine Forest and Mixed Conifer - Frequent Fire ecological response units but low in Semi-Desert Grassland and low to moderate in Pinyon-Juniper Grass ecological response units. For these reasons, there is substantial concern for the persistence of Metcalfe's tick-trefoil on the Tonto National Forest.

Mt. Dellenbaugh sandwort (*Arenaria aberrans*) is a perennial herb and Arizona endemic found throughout north and north-central Arizona. On the Tonto National Forest, there are only two known occurrences at the Tonto Basin and Upper Salt local zones (SEINet 2016). Plants are mostly associated with Pinyon-Juniper Woodland and occasionally Ponderosa Pine Forest and Ponderosa Pine - Evergreen Oak ecological response units. While seral state departure is low (current and projected) for the Pinyon-Juniper Woodland ecological response unit, climate change vulnerability is high for this ecological response unit.

The effects of fire on the viability of Mt. Dellenbaugh sandwort are unclear; however, current conditions show high risk of catastrophic fires beyond what would be expected under the natural range of variation in Ponderosa Pine Forest and Ponderosa Pine - Evergreen Oak ecological response units. Dense, closed-canopy stands; large patch sizes; and high accumulations of coarse woody debris are the primary factors responsible for the increased wildfire risk in these habitat types. No surveys have been conducted to determine the extent of populations in suitable habitat on the Tonto; therefore, the uncertainty (only 2 documented sites) and the degraded site conditions raise substantial concern for the species' persistence.

Pinaleno Mountain rubberweed (*Hymenoxys ambigens* var. *ambigens*) is an Arizona endemic narrowly distributed from the southeast to central part of the state (SEINet 2016, NatureServe 2016). It is known from only one location on the Tonto National Forest, at the Lower Verde zone in the Interior Chaparral ecological response unit. Other potential habitat includes Pinyon Juniper Woodlands and Pinyon Juniper Evergreen Shrub ecological response units.

While threats are unknown, there has been a 10 to 30 percent decline in population numbers, with declines projected to reach 70 percent over the long-term (NatureServe 2016). Reasons for the population declines are unknown. Probably the largest threat to populations are from climate change. Pinyon-juniper habitats, specifically the Pinyon Juniper Woodlands ecological response unit, are highly vulnerable to climate change (reference "Climate Change" section). Therefore, there is substantial concern for Pinaleno Mountain rubberweed on the Tonto National Forest.

Pringle's fleabane (*Erigeron pringlei*). This species is an Arizona endemic found at mountains throughout central and southern Arizona (SEINet 2015, NatureServe 2016). Populations are known from 13 sites on the Tonto National Forest at the Lower Verde, Tonto Basin, Upper Salt, and Lower Salt zones and at mountains in a range of habitat types including Ponderosa Pine - Evergreen Oak, Pinyon-Juniper Evergreen Shrub, Pinyon-Juniper Woodland, Juniper Grass and Interior Chaparral ecological response units. Plants are found near mesic situations and springs and in shady canyons (AGFD 2004).

Current conditions show moderate to high departure among Ponderosa Pine-Evergreen Oak, Pinyon-Juniper Evergreen Shrub, and Juniper Grass ecological response units and low departure among Interior Chaparral and Pinyon-Juniper Woodland ecological response units. Projected conditions show Juniper Grass, Interior Chaparral, and Pinyon-Juniper Woodland ecological response units reaching low departure, while Ponderosa Pine - Evergreen Oak and Pinyon-Juniper Evergreen Shrub ecological response units remain moderately departed after 100 years. Pinyon-juniper types (specifically Pinyon-Juniper Evergreen Shrub) are at significant risk of increased drying, stress, and prolonged drought from climate change (Reference "Climate Change" section).

Current and projected conditions show a moderate to large proportion of closed-canopy states in Ponderosa Pine - Evergreen Oak, Pinyon-Juniper Evergreen Shrub, and Juniper Grass ecological response units, increasing the risk of uncharacteristic wildfire. While direct damage to individuals from fires is low because of the rocky, canyon habitat, intense heating from fires may alter the microclimate and negatively impact populations. Changes in the surrounding vegetation, such as less shady conditions and less mesic situations, may also negatively impact the species. While likely overestimated (plants restricted to mountains), potential habitat makes up 49 percent of the Tonto National Forest. While direct threats are low, nearly 43 percent of the potential habitat (Ponderosa Pine - Evergreen Oak and Pinyon-Juniper Evergreen Shrub ecological response units) is trending away from reference conditions, increasing risk to Pringle's fleabane. For these reasons, there is substantial concern for Pringle's fleabane persistence on the Tonto National Forest.

Ripley wild buckwheat (*Eriogonum ripleyi*) is a low, herbaceous perennial subshrub found at one locality at the Lower Verde zone on the Tonto National Forest. Plants grow on white powdery gypseous limestone of Tertiary lakebed deposits. The single locality on the Tonto represents one of five widely separated localities in central to northwestern Arizona (AGFD 1997). All known occurrences on the Tonto National Forest occupy a relatively small geographic extent, covering roughly 3.86 square miles (SEINet 2016).

Plants are found at calcareous soils in the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit. Nearby communities and potential habitat include Mojave Sonoran Desert Scrub and Pinyon-Juniper Woodland ecological response units. Soils maps identify large areas of potential habitat that have not been surveyed (Phillips 1996 in Lutch 2000). Habitat degradation is apparent, with more than 80 percent of soils in the Sonora-Mohave Mixed Salt Desert Scrub ecological response unit rated as impaired to unsatisfactory. Mojave Sonoran Desert Scrub and Pinyon-Juniper Woodland ecological response units have moderately impaired soils at 50 and 30 percent, respectively. Impaired and unsatisfactory soils can result in unstable soils with reduced hydrological function (plant-available moisture) and nutrient cycling.

Collection for use in gardens is a particular threat to populations on the Tonto. Other threats are the potential expansion of reservoirs and off-road vehicle traffic (with the potential to affect all extant populations). Populations are being extirpated from development and grazing on private land at other sites in the state, so conservation concern is high for populations on the Tonto. The loss of disjunct sites would dramatically reduce the species' range and viability as a whole. The limited known distribution, uncertainty in extent of suitable habitat, and degraded habitat conditions on the Tonto raise substantial concern for Ripley wild buckwheat persistence on the Tonto National Forest.

Rusby's milkwort (*Polygala rusbyi*) is narrow endemic restricted to central Arizona. It is found only at one location on the Tonto National Forest at the Lower Verde zone on white lacustrine outcrops in the Mojave Sonoran Desert Scrub ecological response unit. Habitat loss through land development (private lands) is a large threat to the species rangewide (USDA Forest Service Region 3 sensitive plant list 2013).

On the Tonto, populations may be negatively impacted by recreational use (off-highway vehicles). This site on the Tonto also harbors other at-risk and sensitive species. Fifty percent of the acres in the Mojave Sonoran Desert Scrub ecological response unit are rated as impaired and unsatisfactory. Impaired soils can result in unstable soils with reduced hydrological function (for example, plant-available moisture) and nutrient cycling. The extremely limited habitat, isolated nature of populations, rarity, and degraded habitat conditions pose substantial risk to the persistence of Rusby's milkwort on the Tonto National Forest.

Salt River rock daisy (*Perityle gilensis* var. *salensis*) is an herbaceous perennial and one of the two varieties in *Perityle gilensis*. This variety is geographically separated from the typical variety (*P*. var. *gilensis*) and has notably longer, narrow leaves and a trailing habit. The range of this variety is extremely small. There are only two known sites for the species, separated by a distance of 30 miles. One site is located on the Tonto National Forest along the Salt River Canyon in the Upper Salt zone and the other on the Ft. Apache Indian Reservation.

Suitable habitat is similar to the Gila rock daisy – nearly inaccessible crevices on cliff faces, ledges, and rock outcrops in Mojave Sonoran Desert Scrub, Semi-Desert Grassland, Juniper Grass, and Interior Chaparral ecological response units on the Tonto. The suitable habitat makes up a significant proportion of the Tonto, but plants are only known to occupy a very small portion of the habitat at one locality because they are restricted to cliff faces and rock outcrops. Substrates are igneous bluffs and parent material consists of sandstone and sedimentary rock.

Mentioned threats to the species include dam building and reservoir expansion. While there are no plans to expand reservoirs on the Tonto National Forest, future developments could potentially eliminate the taxon entirely (inundation) because of its limited range to one drainage system (AGFD 2003, Interagency Sensitive Plant Assessment 2004; Wendy Hodgson, personal communication, 2016).

Fire is most likely a low threat given that most sites are associated with desert communities and these communities lack the efficient fuels capable of affecting plants at cliff faces. However, a large proportion of the potential habitat (Juniper Grass and Interior Chaparral ecological response units) further upstream the Salt River Canyon is capable of producing hot fires with the potential to negatively impact the Salt River rock daisy. While direct negative impacts from fires are low, severe fires may damage individuals (from intense heating) and alter local site conditions. Current conditions show low to moderate departure for Interior Chaparral and Juniper Grass ecological response units. Juniper Grass has an excess coarse woody debris, large patch sizes, and a loss of effective vegetative groundcover capable of carrying nonlethal surface fires. As a result, fire return intervals are much longer and fires are burning at mixed to high severities, deviating away from reference conditions of frequent, nonlethal fires. While the Juniper Grass ecological response unit is projected to reach low seral state departure, 34 percent of the ecological response unit will still remain in a denser state in the future, rendering it susceptible to outbreaks of insects, pathogens, and stand-replacing wildfire. The extremely limited range and impaired habitat conditions over a large percent of the potential habitat make the Salt River rock daisy particularly vulnerable to extirpation on the Tonto.

Sierra Ancha fleabane (*Erigeron anchana*) is a perennial herb narrowly distributed in central Arizona at elevations between 3,500 and 7,000 feet. A majority of all known sites are located on the Tonto National Forest. Sierra Ancha fleabane is the largest of the *Erigeron pringlei* complex. Populations are found at the Lower Verde, Tonto Basin, and Upper Salt local zones. The populations at the Sierra Ancha Mountains on the Tonto are considered the center of the species geographic range (AGFD 2003). Plants are found at granite cliff faces, below roads at major drainages, and scattered along cliff faces near the bottom of canyons in Ponderosa Pine - Evergreen Oak, Pinyon-Juniper Evergreen Shrub, and Interior Chaparral ecological response units on the Tonto.

While potential direct threats are low (species inhabits rock crevices and rock faces), current conditions show high fuel loads from the accumulation of coarse woody debris and closed-canopy conditions (in Ponderosa Pine - Evergreen Oak and Pinyon-Juniper Evergreen Shrub ecological response units) capable of producing very hot fires. Additionally, the highest departure for the Ponderosa Pine - Evergreen Oak ecological response unit is at the Upper Salt zone where 7 of 9 sites on the Tonto are located.

While the effects of fire are unknown for Sierra Ancha fleabane, intense heating can potentially damage individuals and alter habitat microclimate. The Pinyon-Juniper Evergreen Shrub ecological response unit is projected to trend towards reference conditions but will still remain departed after 100 years, with 31 percent of the acres in closed-canopy states, increasing the risk of wildfire. Additionally, pinyon-juniper habitats are at significant risk of increased drying, stress, and prolonged drought from climate change. Seventy-seven percent of the Pinyon-Juniper Evergreen Shrub ecological response unit on the Tonto is assessed to have moderate to high vulnerability to climate change. The Tonto National Forest has a significant influence on the viability of the species because nearly the entire range is located on the Tonto. While direct impacts are low, current and projected conditions show the habitat trending away from reference conditions. For these reasons, there is substantial concern for Sierra Ancha fleabane persistence on the Tonto National Forest.

Tonto Basin agave (*Agave delamateri*) is a perennial succulent found at the Lower Verde, Tonto Basin, and Upper Salt local zones. The greatest concentration of sites are at the Tonto Basin zone near the Sierra Ancha and Mazatzal Mountains. Tonto Basin agave reproduces by pups or clones from the base of the parent plant. Little is known about flowering, seed, and fruit development but it is suspected that specific climatic conditions may influence or inhibit flower and fruit development (AGFD 2003).

On the Tonto, plants are usually found on south and southwest-facing slope edges and atop benches, occasionally on northeast facing gentle slopes in the Mojave Sonoran Desert Scrub ecological response unit and occasionally Interior Chaparral and Juniper Grass ecological response units. Typical substrates include cobbly and gravelly, deep and well-drained soils at elevations from 2,300 to 5,100 feet. Populations are often associated with prehistoric sites.

Fires may be a potential threat to agaves where vegetation is dense. While current conditions show an overall low departure (seral state) for the Mojave Sonoran Desert Scrub ecological response unit, 55 percent of the acres are in fire regime condition class III, indicating high departure in fire regime. Increased shrub densities and exotic grasses have contributed to the altered fire regime (increased fire frequency and severity) in the Mojave Sonoran Desert Scrub ecological response unit. This ecological response unit is projected to trend away from reference conditions resulting in decreased cacti, shrub, and tree cover and an increase in exotic grass cover (increasing the risk of uncharacteristic fire).

While current and projected conditions show low seral state departure for the Interior Chaparral ecological response unit, 78 percent of acres are classified as fire regime condition class II, indicating a moderate departure in fire regime. While the Interior Chaparral ecological response unit mostly experienced high-severity, stand-replacing fires at fire return intervals of 35 to 100 or more years, some areas experienced much shorter fire return intervals of 0 to 35 years. Currently, fire return intervals average 128 years in the Interior Chaparral ecological response unit. As a result of fire suppression and exclusion, some areas may experience very hot fires due to the build-up of dead fuel matter.

While there are currently no plans to expand reservoirs on the Tonto National Forest, future developments (Roosevelt Lake) can potentially eliminate populations (inundation). Under stressed conditions, plants are susceptible to agave snout weevil damage (beetle-transmitted fungus) and can lead to clone mortality.

Agave roots are shallow and spread outward to capitalize on moisture in the upper soil layers. While direct damage to individuals from recreation (such as off-highway vehicle use) is low, soil compaction at sites may reduce plant-available moisture. As with most agaves, Tonto Basin agave is susceptible to root rot and requires well-drained soils (AGFD 2003). A loss of soil productivity and function is already evident; current conditions show nearly 50 percent of Mojave Sonoran Desert Scrub soils are rated as impaired. These factors, along with the limited reproductive potential, increase the likelihood of local extinction or extirpation of Tonto Basin agave on the Tonto National Forest.

Verde breadroot (*Pediomelum verdiensis*). This species is a perennial herb with an extremely limited range centered in the vicinity of Camp Verde (SEINet 2015). Welsh and Licher (2010) recently described the species. A few populations are estimated to be stable but general information, such as limiting factors and the magnitude of current and potential threats for the species, is lacking. No searches have been conducted to confirm sites on the Tonto but because populations are very close to the Tonto National Forest boundary (10 miles from Pine, Arizona), the species is considered a potential species of conservation concern until surveys confirm its absence in the plan area.

Typical habitat includes high desert scrub on Verde limestone substrate and sandy ridges. The Mojave Sonoran Desert Scrub ecological response unit represents suitable habitat on the Tonto National Forest, and Verde breadroot is most likely restricted to the Lower Verde zone on the Tonto. The Mojave Sonoran Desert Scrub ecological response unit makes up 22 percent of suitable habitat on the Tonto but because of the species' rarity, it is assumed plants occupy a small proportion of the suitable habitat.

While current conditions show an overall low seral state departure for the Mojave Sonoran Desert Scrub ecological response unit, 55 percent of the acres are in fire regime condition class III, indicating high departure in fire regime. Increased shrub densities and exotic grasses at sites have contributed to the altered fire regime (increasing the risk of fire frequency and severity) in the Mojave Sonoran Desert Scrub ecological response unit. This ecological response unit is projected to trend away from reference conditions resulting in decreased cacti, shrub, and tree cover and an increase in exotic grass cover (increasing the risk of uncharacteristic fire).

While the species is documented to occur in disturbed areas, the degree to which it can tolerate repeated ground disturbance (such as off-highway vehicle use or hiking) is unknown. Nearly 50 percent of Mojave Sonoran Desert Scrub soils are rated as impaired, indicating a loss in soil function and productivity. While threats are poorly known for the species, the extremely limited range and departed current and projected habitat conditions pose substantial risk to Verde breadroot.

Reptiles

Bezy's night lizard (*Xantusia bezyi*) has a limited distribution on the Tonto National Forest. It is considered endemic, occurring east of the Verde River from the Mazatzals Mountains and Superstition Mountains east to the base of the Pinal Mountains and south across the Gila River to the Galiuro Mountains. The population numbers for the species are unknown. The lizards occupy crevices in granite boulders in upland Sonoran desert and interior chaparral. This species is difficult to view as they are considered a rock crevice specialist and always remain hidden (Jones 2009). Their diet consists primarily of ants and other arthropods that occur in the crevices.

Currently, the ecological response units occupied by the Bezy's night lizard are Mojave-Sonoran Desert Scrub and Interior Chaparral. These ecological response units are in moderate and low seral state departure, respectively. Fire regime condition classes for the Mojave-Sonoran Desert Scrub ecological response unit indicate a high degree of departure, while the Interior Chaparral ecological response unit is in moderate departure from reference conditions. Habitat loss from fires is the biggest threat due to the limited distribution of this species. Fires have the potential to increase habitat loss in desert communities where exotic grasses are established. A catastrophic event may negatively affect this long-lived species (approximately 10 years) that is thought to have a low reproductive output (1 to 2 live young per year).

Due to this species' endemic nature and limited range, any threat could severely reduce population numbers.

Primary Threats to Special Habitat Features and Associated Species

The following shows primary threats to special habitat features and the species associated with those features. Species with an asterisk (*) are federally listed species; all others are potential species of conservation concern.

Tree Features (cavities, snags, leaves, bark, downed logs, leaf or forest litter)

Primary Threats

- Fire can consume tree features directly, resulting in the loss of nesting, breeding, and roosting habitat. Intense smoke from fire can displace species and cause direct mortality.
- Timber harvest activities may result in direct damage and loss of trees and snags.
- Large-scale outbreaks of insects or disease could threaten large areas of habitat.

Associated Species of Conservation Concern and Federally Listed Species

- Mexican spotted owl
- Western red bat
- Desert purple martin
- Pacific wren
- Olive-sided flycatcher
- Sulphur-bellied flycatcher
- Yellow-eyed junco
- Lewis's woodpecker

Rock Features (canyons, cliffs, crevices, outcrops, talus slopes)

Primary Threats

- Activities including recreational rock climbing, caving, mining, construction and vandalism, can disturb or damage habitat.
- Removal of surface rock causes direct mortality and damages habitat.
- Alterations of the rock surfaces, such as removing rock through excavation or rock climbing, can alter the habitat enough to disrupt or prevent plant establishment.
- Trampling of plants in crevices causes direct mortality creating unstable rocks.

Associated Species of Conservation Concern and Federally Listed Species

- Mexican spotted owl*
- American dipper
- Bezy's night lizard
- Phoenix talussnail
- Mapleleaf false snapdragon
- Salt River rock daisy
- Gila rock daisy
- Fish Creek rock daisy
- Hodgson's fleabane
- Pringle's fleabane
- Arizona hedgehog cactus*
- Arizona cliffrose*

Aquatic Features (riparian areas, springs, permanent water)

Primary Threats

- Groundwater depletion and streamflow diversion, roads, trails, facilities, nonnative plant species and upland species encroachment, uncharacteristic fire in riparian and adjacent areas, mining, or unmanaged herbivory lead to loss or damage of riparian characteristics.
- Disturbance to soil in these areas due to unmanaged herbivory, dispersed camping, or construction activities can decrease plant cover.
- Spring developments for livestock or wildlife decrease water available for local ecosystems. Trampling further degrades these areas. Trampling in wet areas can also spread chytrid disease.
- Invasive species compete with native species for food or are predaceous on native species in aquatic features (bullfrog).

Associated Species of Conservation Concern and Federally Listed Species

- Mexican spotted owl*
- Southwestern willow flycatcher*
- Yellow-billed cuckoo*
- Yuma Ridgeway’s rail*
- Chiricahua leopard frog*
- Narrow-headed gartersnake*
- Northern Mexican gartersnake*
- MacGillivray’s warbler
- Pacific wren
- Red-faced warbler
- Sulphur-bellied flycatcher
- American dipper
- Western grebe
- Clark’s grebe
- Broad-billed hummingbird
- Fossil springsnail
- Parker’s cyllopeus riffle beetle
- Gila trout*
- Gila chub*
- Gila longfin dace
- Gila topminnow*
- Desert pupfish*
- Razorback sucker*
- Colorado pikeminnow*
- Headwater chub*
- Roundtail chub*
- Loach minnow*
- Spikedace*
- Grand Canyon century plant
- Broadleaf lupine
- Arizona giant sedge
- Blumer’s dock
- Aravaipa sage
- Fish Creek fleabane

Meadows and Small Openings

Primary Threats

- Unmanaged herbivory can change local conditions and invertebrate communities.
- Unmanaged herbivory can stunt growth of sensitive plants and remove flower parts preventing seed production.
- Encroachment by woody vegetation eliminates grasses and forbs and decreases the size and ecological function of these features.

Associated Species of Conservation Concern and Federally Listed Species

- Lewis’s woodpecker
- Olive-sided flycatcher
- Alamos deer vetch
- Blumer’s dock
- Metcalfe’s tick-trefoil

Soil Features (soil type, soil permeability and soil condition)

Primary Threats

- In some places, invasive species can outcompete native species found only special soil types.
- Disturbance to soils from dispersed camping, off-highway vehicle use, unmanaged herbivory, or mining can negatively impact species.

Associated Species of Conservation Concern and Federally Listed Species

- Phoenix talussnail
- Fish Creek fleabane
- Verde breadroot
- Ripley wild buckwheat
- Horseshoe deer vetch
- Aravaipa sage
- Arizona cliffrose*

Species Risk Analysis

Potential species of conservation concern are presented in table 113. These potential species of conservation concern have been found by external entities (including the U.S. Fish and Wildlife Service, the Southwestern Region of the Forest Service, the Arizona Game and Fish Department, and others) to already be at-risk for extinction. In addition, we confirmed these potential species of conservation concern were native to the planning area and their persistence was at risk. These species, in addition to federally listed species relevant to the plan area (table 110), will be considered as the Tonto National Forest staff evaluate needs for change to the current forest plan.

The potential species of conservation concern identified in this assessment meet the requirements set forth in the final directives (Forest Service Handbook 1909.12). Some have been linked to current ecological response units in moderate or high departure from reference condition or management actions under the current plan that may be negatively affecting either the ecological response unit or populations on the Tonto National Forest. Many of these species are also affected by activities outside the plan area or beyond Forest Service control; it is important to recognize the limits to agency authority and the inherent capability of the Tonto National Forest.

These potential species of conservation concern and federally listed species will be considered as the plan revision process moves forward and considers the need for change to the existing forest plan. The coarse-filter/fine-filter approach used to assess species will also be carried forward through the next steps. Plan components will be developed to maintain or restore conditions for ecological integrity and diversity in the plan area. Working toward the goals of ecosystem integrity and diversity with connected habitats that can absorb and recover from disturbance, proper management can maintain and restore conditions that support the abundance, distribution, and long-term persistence of native species. In addition, the fine filter approach will provide for specific habitat needs or other ecological conditions for those species that are not met through the coarse-filter approach. The species for which the 2012 Final Planning Rule requires fine-filter plan components are federally listed threatened and endangered species, proposed and candidate species, and species of conservation concern.

Summary of Conditions, Trends, and Risks

The Tonto National Forest is home to hundreds of animal and plant species, some of which are found only within its boundaries. Others have increased their reliance on Forest Service-managed lands due to stressors outside the Tonto National Forest boundaries.

Federally recognized and potential species of conservation concern were identified and evaluated for the Tonto National Forest. A total of 22 federally recognized species: 2 endangered and experimental nonessential, 12 endangered, 6 threatened, and 2 proposed threatened. Of these, there are 3 mammals, 4 birds, 1 amphibian, 2 reptiles, 10 fish, and 2 plants. Of the 162 species considered as potential species of conservation concern, 111 were determined, through best available scientific information, to be secure or there was insufficient information to conclude there is a substantial concern about the species' capability to persist in the plan area over the long term. Fifty-one potential species of conservation concern were carried forward: 1 amphibian, 1 reptile, 14 birds; 1 fish, 4 invertebrates, 3 mammals, and 27 plants.

Wildlife and plant species identified as at-risk by a number of different entities were considered. The species that were ultimately considered to be at-risk met the following criteria: (1) they met the initial requirements according to the 2012 Planning Rule; (2) they had been documented on the Tonto National Forest; and (3) they had the potential to be both positively and negatively affected by Forest Service management activities. An overall risk assessment for each species was calculated from data identifying the status of historic, current, and future population trends and associated ecological response units and from data identifying direct threats to the species or to key ecosystem characteristics.

If management activities focus on ecosystem integrity and diversity goals by including connected habitats that can absorb disturbance, ecological conditions would be effectively restored and maintained. These improved ecological conditions would increase the diversity of plant and animal communities and support the abundance, distribution, and long-term persistence of common and secure, imperiled, or vulnerable native species. Species-specific plan components in each ecological response unit will be developed for those species with additional or key ecosystem characteristics or where ecological conditions are not otherwise met. Additionally, if new scientific information indicates a species may warrant being added to or removed from the list of at-risk species, the rationale for such action can be documented.

Chapter 8. Air Quality

Air provides the foundation on which life depends. It provides the following functions:

- Oxygen for respiration by plants and animals,
- Carbon dioxide for photosynthesis, and
- Nitrogen for plant nutrition.

Air is key to global redistribution of biological and physical byproducts. Air enables transportation (wind for sails, lift for airplanes) and provides energy (wind turbines).

Air quality has long been recognized as an important resource to protect on national forests. Not only does the public value the fresh air and sweeping views national forests can provide, but forest health, water quality, and fisheries are also highly valued and can be negatively impacted by poor air quality.

The 2012 Planning Rule requires national forests to consider air quality when developing forest plan components. This section describes the air quality on, and affecting, the Tonto National Forest. The purpose is to evaluate available information about air quality and describe the current conditions and trends regarding air quality in the plan area. This information will be used to anticipate future conditions and to determine if trends in air quality pose risks to system integrity at the national forest level. Additionally, this section will identify information gaps about air quality and any uncertainty with the data.

This section follows the guidance of, and contains all components specified by, Forest Service Handbook, chapter 10, section 12.21 (Forest Service Handbook 1909.12):

- Airsheds relevant to the plan area.
- Location and extent of known sensitive air quality areas, such as Class I areas, nonattainment areas, and air quality maintenance areas.
- Emission inventories, conditions, and trends relevant to the plan area.
- Federal, State, and Tribal implementation plans for regional haze, nonattainment, or maintenance areas (including assessing whether Forest Service emission estimates have been included in the appropriate agency implementation plans).
- Critical loads.

This section contains a summary of the complete air quality analysis, which can be found in the Tonto National Forest Air Quality Assessment Report. For this assessment, the best available science was used. Uncertainty in the assessment has been documented where relevant. Government data that has met strict protocols for data collection was used to assess the current conditions and trends for ambient air quality, visibility, emissions inventories, and deposition. The critical load information was based on multi-agency government research and analysis and follows Forest Service protocols.

Identification of Airsheds

Airsheds are similar to watersheds; they are defined geographic areas frequently affected by the same air mass because of topography, meteorology, or climate. The difference with airsheds is that air masses and air pollutants move between airsheds mostly based on larger meteorological patterns, rather than primarily by topography, as with water flowing through a watershed. Airsheds, like watersheds, can be defined at multiple scales.

The airshed of the Tonto National Forest consists of three geographical regions: (1) all of its landscape within its defined boundaries; (2) immediately adjacent lands to the north, east, and west; and (3) parts of the southern Arizona deserts to the west and southwest, parts of the Mogollon Rim area, and parts of the mountainous areas east of the Tonto National Forest. This air quality assessment is limited to Tonto National Forest lands and the Phoenix metropolitan area. This region consists of all or part of three counties: central and eastern Maricopa, virtually all of Gila, and northern Pinal Counties. Figure 79 illustrates the Tonto National Forest airshed with arrows indicating the daytime upslope flows (valley-to-mountain) and the nighttime downslope flows.

Figure 79. Tonto National Forest airshed

Sensitive Air Quality Areas

The basic framework for controlling air pollutants in the United States is mandated by the Clean Air Act, originally adopted in 1963 and amended in 1970, 1977, and 1990. The Clean Air Act was designed to protect and enhance air quality. Section 160 of the Clean Air Act requires measures “to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreation, scenic, or historic value.”

Congress classified 158 areas as Class I areas in existence on August 7, 1977, including national parks larger than 6,000 acres and national wilderness areas larger than 5,000 acres (Clean Air Act Section 162). Class I areas have been designated Act as deserving the highest level of air quality protection. These mandatory Class I areas may not be reclassified to a less protective classification.

There are 12 mandatory Class I areas in Arizona (figure 80). Four of them, all designated wilderness, are near or within the Tonto National Forest: Pine Mountain Wilderness, Mazatzal Wilderness, Sierra Ancha Wilderness, and Superstition Wilderness. In addition, the Tonto National Forest includes four other wilderness areas designated after 1977: Hellsgate Wilderness, Salome Wilderness, Four Peaks Wilderness, and Salt River Canyon Wilderness. Although they are not Class I areas, they are managed as if they had this status.

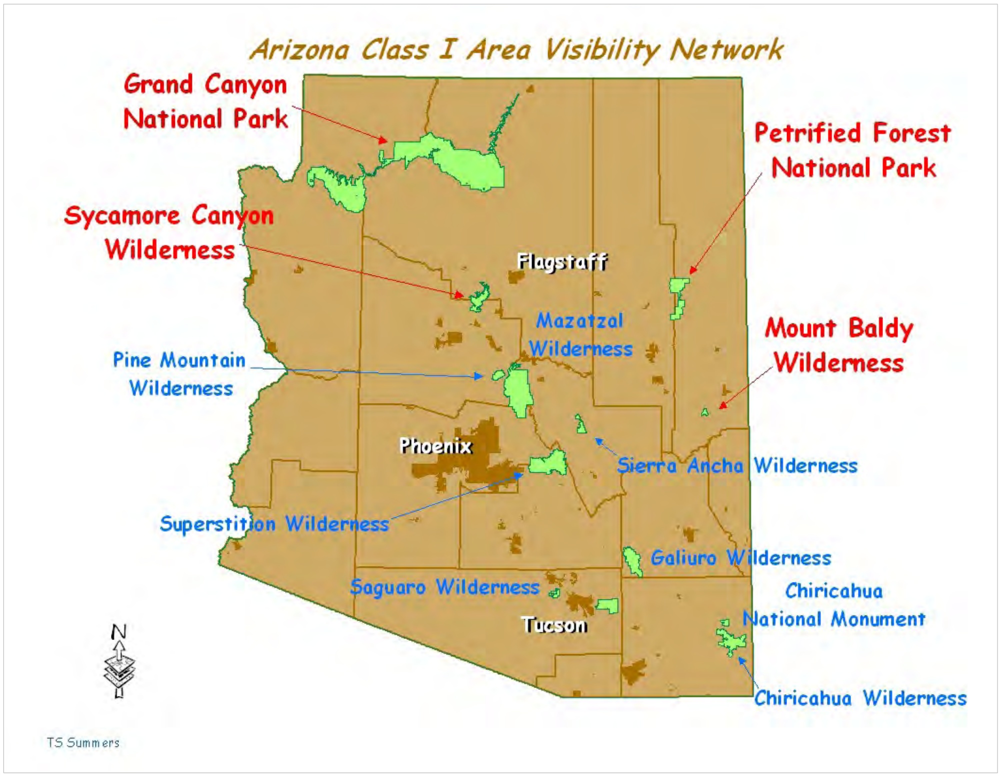


Figure 80. Arizona Class I areas (Source: ADEQ 2003)

Nonattainment Areas

In addition to the Class I areas, sensitive areas also include those portions of south-central Arizona which have, in the recent past or at present, failed to achieve various air quality standards. Several such nonattainment areas lie near the Tonto National Forest or include parts of its domain: the Maricopa County particulate matter 10 and ozone nonattainment areas, the Payson particulate matter 10 nonattainment area, Miami nonattainment areas for sulfur dioxide and particulate matter 10, and the Hayden nonattainment areas for particulate matter 10 and sulfur dioxide. Each one is described in more detail in the Tonto National Forest Air Quality Assessment Report.

Air Quality Standards

The purpose of the Clean Air Act is to protect and enhance air quality, while at the same time ensuring the protection of public health and welfare. The Act established national ambient air quality standards which represent maximum air pollutant concentrations to protect public health and welfare. The pollutants regulated by national ambient air quality standards are called criteria air pollutants and consist of carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, lead, particulate matter 10, and particulate matter 2.5.

The U.S. Environmental Protection Agency established national ambient air quality standards for specific pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards:

- The primary standards represent the maximum allowable atmospheric concentrations that may occur and still protect public health and welfare and include a reasonable margin of safety to protect the more sensitive individuals in the population.
- Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

Under the Clean Air Act, State agencies and Tribes are given primary responsibility for air quality management. For areas not achieving a national air quality standard, the agencies are responsible for developing State or Tribal implementation plans through which they identify how national ambient air quality standards compliance will be achieved. For these nonattainment areas, the State or Tribe is required to develop a plan to improve air quality to the degree that it meets the standard; once achieved, the area is designated as a maintenance area.

The greater part of the Phoenix area, including the southwestern and southern reaches of the Tonto National Forest, has been, and remains in, nonattainment for ozone; furthermore, until this year, this region was also in nonattainment for particulate matter 10 microns and smaller (particulate matter 10). Although carbon monoxide concentrations in Phoenix frequently exceeded the standard in the 1970s and 1980s, levels of this pollutant have been reduced to be well within the standard and will not be considered in this air quality assessment.

Sulfur dioxide concentrations in and near Arizona smelter towns exceeded standards frequently in the 1970s and 1980s but are now achieving these standards. Because the Globe-Miami copper mining area is surrounded by the Tonto National Forest, and because the Hayden copper mining and smelting area lies within 50 kilometers of the Tonto National Forest boundary, both sulfur dioxide and lead remain of concern. Like other Class I areas close to large cities, the four Class I areas in or near the Tonto National Forest are subject to pollutant transport from Phoenix. Because of its proximity to urban Phoenix, the Tonto National Forest receives not only its transported air pollution but also its people; visitor-days are much higher in the Tonto National Forest than in other Arizona forests further from its capital city.

Table 119 presents those standards relevant to this air quality assessment for the Tonto National Forest. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air ($\mu g/m^3$). Gaseous pollutants are usually, though not always, expressed as ppm or ppb; particulate pollutants are only expressed as mass per volume, usually as micrograms per cubic meter. Particulate matter 2.5 and particulate matter 10 are particles smaller than 2.5 and 10 microns, respectively.

Table 119. National ambient air quality standards

Pollutant [final rule cited]	Primary/ Secondary	Averaging Time	Level	Form
Lead[1] [73 FR 66964, Nov 12, 2008]	Primary and secondary	Rolling 3-month average	0.15 μg/m^3	Not to be exceeded
Ozone[2] [73 FR 16436, Mar 27, 2008]	Primary and secondary	8-hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particulate matter 2.5 Particle Pollution Dec 14, 2012	Primary	Annual	12 μg/m^3	Annual mean, averaged over 3 years
Particulate matter 2.5 Particle Pollution Dec 14, 2012	Secondary	Annual	15 μg/m^3	Annual mean, averaged over 3 years
Particulate matter 10 Particle Pollution Dec 14, 2012	Primary and secondary	24-hour	35 μg/m^3	98th percentile, averaged over 3 years
Particulate matter 10 Particle Pollution Dec 14, 2012	Primary and secondary	24-hour	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
sulfur dioxide[3] [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]	Primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
sulfur dioxide[4] [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]	Secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year
nitrogen dioxide[5] [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]	Primary	1-hour	100 ppb	98th percentile, averaged over 3 years
nitrogen dioxide[6] [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]	Primary and secondary	Annual	53 ppb	Annual Mean

1. Final rule for lead signed October 15, 2008. The 1978 lead standard (1.5 µg/m3 as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.
2. Final rule for ozone signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place. In 1997, EPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The 1-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to 1.
3. Final rule for SO2 signed June 2, 2010. The 1971 annual and 24-hour SO2 standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.
4. Final rule for SO2 signed June 2, 2010. The 1971 annual and 24-hour SO2 standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.
5. The official level of the annual nitrogen dioxide standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.
6. The official level of the annual nitrogen dioxide standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

Emissions

Air quality effects on national forests are generally traceable to the original sources of emissions; therefore, air emissions information provides an overview of the magnitude of air pollution and is important in understanding air quality within the national forest (for example, visibility and acid deposition). For example, improving visibility conditions in Class I areas would generally be associated with corresponding decreases in emissions for visibility precursor pollutants.

Emissions information is generally tracked for pollutants that have health-based air quality standards such as sulfur dioxide, particulate matter, lead, and ozone precursor emissions. This picture is made more complicated for the case of ozone and particulate matter.

Instead of being directly emitted, ozone and its accompanying photochemical oxidant compounds are formed by sunlight acting on two groups of precursors: volatile organic compounds and nitrogen oxides. Therefore, emissions of these two ozone precursor groups are tracked in ozone nonattainment areas such as metropolitan Phoenix.

Particulate matter emissions (and concentrations) are generally broken into two overlapping categories based on their size: fine particulate matter, better known as particulate matter 2.5, is particles 2.5 microns in diameter or smaller; particulate matter 10, particles 10 microns and smaller. The latter is sometimes called coarse particulate matter, even though this term actually refers to particles between 2.5 and 10 microns in diameter. The size fraction of particulate matter 10 includes particulate matter 2.5; but as they are generally measured separately and have separate standards, both size fractions are examined in this assessment. Smaller particles have greater health effects because they are more easily inhaled deep into the lungs.

Nearly all particulate matter in the size range of 2.5 to 10 microns, which makes up most of the mass of particulate matter 10, is emitted directly through various mechanical, industrial, and natural processes, However, a considerable portion of fine particulate concentrations is formed through atmospheric chemical reactions. Although not directly examined in this assessment, these particles are called secondary organic aerosols and account for much of the visibility degradation in urban and rural areas. Gaseous sulfur dioxide and particulate lead are emitted directly and are accounted for in this way.

Sulfur Dioxide Emissions

In south-central Arizona, sulfur dioxide emissions are dominated by the smelting and refining of copper ores. Sulfur dioxide emissions from copper mining and smelting activities have been drastically reduced over the past four decades through a combination of closing several smelters, emphaszing refining copper through leaching and electro-winning instead of smelting, and installing better control devices on the smelters still operating. Metropolitan Phoenix also produces sulfur dioxide emissions, although the countywide total is quite small, slightly less than 1,000 tons per year. The relative magnitude of sulfur dioxide emissions in the Tonto National Forest area, expressed as countywide emissions for the counties of Maricopa, Pinal, and Gila, are illustrated in table 120 below. First is an emission density summary (shown in the box below) that demonstrates the predominance of Gila over the other two counties in sulfur dioxide emission densities. Of the three counties, Gila is the one of paramount importance to the Tonto National Forest.

Table 120. Sulfur dioxide average emissions per county

County	Sulfur Oxides Emissions (Average per square mile)
Maricopa	0.041 to 0.31 ton/mile^2
Pinal	0.0096 to 0.036 ton/mile^2
Gila	0.98 to 6.7 ton/mile^2

Source: U.S. EPA 2014

Volatile Organic Compound Emissions

Volatile organic compound emissions are one of two ozone precursor groups. In an urban area, volatile organic compound emissions are released in all combustion processes, especially involving transportation. They are emitted through the evaporation of volatile solvents. They are emitted into the atmosphere as biogenic volatile organic compound emissions through the photosynthesis of green plants. In the 2014 Maricopa County emissions inventory (Maricopa County 2014), volatile organic compound emissions are dominated by the biogenic, followed by loss and evaporation of solvents, on-road vehicle traffic, and several lesser contributors

Nitrogen Oxides Emissions

Nitrogen oxides emissions occur as a result of fuel combustion in industrial or commercial emission sources (for example, power generation facilities), in mobile sources (for example, cars, trucks, buses), or in the nonroad mobile emission sector. The nonroad mobile emission sector includes diesel-powered, heavy earth-moving and mining vehicles and engines; aircraft; trains; and other vehicles and equipment not licensed for travel on public highways. In the 2014 Maricopa County emissions inventory (Maricopa County 2014), nitrogen oxides emissions are dominated by on-road vehicle traffic, nonroad mobile sources, and several lesser contributors. Forty-three percent of volatile organic compounds originate from photosynthetic plants, while only 1 percent of the total nitrogen oxides emissions are biological. This biogenic nitrogen oxide is from the action of nitrogen-fixing bacteria in legumes in the soil.

With the rapid growth of metropolitan Phoenix since the end of World War II, and with its continued robust growth since air pollution monitoring began about 1970, nitrogen oxides emissions from this urban area have most assuredly increased.

Particulate Matter Emissions

Particulate matter comes from a variety of sources, both natural and human caused. In metropolitan Phoenix, according to the 2014 inventory from Maricopa County (Maricopa County 2014), the emissions distribution can be broken down into eleven broad categories, which include one mostly natural source – windblown dust (12 percent of the total) – and a variety of human-caused emissions. The four highest contributors to the annual emission totals are as follows:

1. On-road mobile vehicle traffic (31 percent) (mostly resuspended dust from paved roads, followed by unpaved road traffic, and then exhaust).
2. Fugitive dust from off-road vehicles being used for recreation (23 percent).
3. Industrial emissions from the smaller businesses and facilities not requiring a point-source permit (11 percent).
4. All the various agricultural activities (9 percent), such as tilling, harvesting, and vehicle traffic on unpaved farm roads.

Prevailing daytime winds from the southwest and west transport these particles to the Tonto National Forest and beyond, especially for the smaller particles (particulate matter 2.5) with the longer atmospheric residence times. Of special concern for the Tonto National Forest is the countywide contribution of recreational off-road vehicles – ranking second overall and amounting to nearly a quarter of the total emissions. Restricting this source on high-pollution advisory days has been part of the Tonto National Forest management responsibilities for a number of years.

Ambient Air Quality

While emissions play an important role in determining overall air quality for a given area, air quality evaluations are also based, in part, on ambient concentrations of pollutants in the air. The Environmental Protection Agency is primarily concerned with air pollutants that cause adverse health effects. The Forest Service also uses these ambient concentrations to determine how pollutants such as ozone, particulate matter, and sulfur dioxide, impact forest resources. Because ambient air quality measurements provide quantitative information, they can also be meaningfully incorporated into air quality models.

Visibility measurements are from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network's three stations within the Tonto National Forest: one at Tonto National Monument, a second in Queen Valley, and the third in the Sierra Ancha Wilderness Area. For atmospheric deposition, the records from the Clean Air Status and Trends Network (CASTNET) site are reviewed. This site, at Chiricahua National Monument in southeast Arizona, is closest in proximity and landscape similarity to the Tonto National Forest. The intent of this section is to present a picture of the emission-producing activities, the emissions themselves, and the various ambient measurements of pollutants that affect the Tonto's ecosystem.

Ozone Concentrations

The major constituent of photochemical smog, ozone, is not emitted directly into the atmosphere but instead is formed by the reaction between nitrogen oxides emissions and volatile organic compounds emissions in the presence of sunlight. The highest concentrations of ozone occur from May through August and, on any given day, from about noon until two hours before sunset.

Excessive ozone concentrations have a detrimental impact on human health and the environment. Elevated ozone levels can cause breathing problems, trigger asthma, reduce lung function, and lead to increased occurrence of lung disease. Ozone also has potentially harmful effects on vegetation, which is usually the principal threat to forested ecosystems. It can enter plants through leaf stomata and oxidize tissue, causing the plant to expend energy detoxifying and repairing itself at the expense of added growth. Damage to plant tissue can be more pronounced where the detoxification and repair does not keep up with the ozone exposure. The mesophyll cells under the upper epidermis of leaves are particularly sensitive to ozone. Ozone damage can generate a visible lesion on the upper side of a leaf, termed oxidant stipple. Other symptoms of elevated ozone exposure may include chlorosis, premature senescence, and reduced growth. These symptoms are not unique to ozone damage and may also occur from other stresses on plant communities such as disease, insect damage, or both.

Measurements taken at three different locations on the Tonto National Forest since 1997 show a slight, gradual, and steady decline in ozone concentrations. In addition, ozone monitors in the vicinity of the Tonto, both in Maricopa County and in Pinal County, demonstrate slightly decreasing concentrations. Metropolitan Phoenix remains a nonattainment area for ozone, meaning the Federal standard has been exceeded at one or more monitoring sites through the years. This ozone is generally transported into the Tonto National Forest during daylight hours; but, after sunset when photochemical activity ceases, the concentrations diminish rapidly to lower levels unlikely to pose a health risk to people or ecosystems.

Particulate Matter Concentrations

Large cities or extensive, active agricultural areas in arid climates, including the south-central deserts of Arizona, have considerable problems attaining particulate matter 10 standards. The air quality of the Tonto National Forest is subject to concentrations of particulate matter 10 considerably above background levels due to the following:

- Transported emissions from metropolitan Phoenix and its environs.
- Emissions within the Tonto National Forest itself.
- Emissions from Payson.
- Emissions from the copper mining and smelting areas of Gila and Pinal Counties.

Airborne particulate matter remains a health threat, a nuisance, and a safety hazard to transportation, whether standards are officially violated or not.

On the southern border of Tonto National Forest, particulate matter 10 is monitored in the Miami-Globe area at two locations, and both show a slight decrease in this pollutant's concentration. Numbers from the monitor in Hayden area indicate a dramatic drop in particulate matter 10 concentrations from around 100 micrograms per cubic meter to about 40 micrograms per cubic meter.

On the western border of the Tonto National Forest, there are two monitors: one in Apache Junction and another in the Ft. McDowell Indian Community. While concentrations in Ft. McDowell have decreased from 60 micrograms per cubic meter in 2006 to about 45 in 2011, the concentrations in Apache Junction have increased from under 60 to about 80 micrograms per cubic meter.

Payson used to have a rather severe particulate matter problem associated with wood burning for heating homes in the winter. However, the long-term trend has been a dramatic improvement in air quality along with the particulate air quality of the surrounding Tonto National Forest lands. Particulate concentrations in Payson have declined from over 120 micrograms per cubic meter to about 40 micrograms per cubic meter.

Particulate matter 2.5 data are available from several monitoring sites in both Pinal and Maricopa Counties, with metropolitan Phoenix having the most. Long-term monitoring records show that while the annual standard has been achieved, the 24-hour standard is infrequently exceeded, usually around the Christmas-New Year's holiday season (Domsky 2014). With the exception of the holiday season through the years, the 98th percentile, 24-hour average particulate matter 2.5 concentrations ranged from 10 to 30 micrograms per cubic meter, with some minor year-to-year variability. The 24-hour national ambient air quality standard for particulate matter 2.5 is 35 micrograms per cubic meter, based on the 98th percentile concentration averaged over three years. Particulate matter 2.5 monitoring has been conducted within the Tonto National Forest at the three IMPROVE sites; the concentrations there, averaged over the requisite three-year period, are within the standards.

Sulfur Dioxide Concentrations

As expected from the sulfur dioxide emissions distribution among counties, metropolitan Phoenix has consistently recorded quite low concentrations in contrast to Gila County, given its proximity to the high copper activity areas of Globe-Miami and Hayden. The 99th percentile of the annual, one-hour daily maximum concentrations in Globe and Hayden is 10 to 15 times as high as those in Scottsdale. Tonto National Forest lands, especially in the Globe-Miami area, are receptor areas for sulfur dioxide concentrations and deposition from the nearby copper mining activities. Metropolitan Phoenix has little to extremely minimal effects on downwind concentrations of sulfur dioxide within the Tonto National Forest.

Lead Concentrations

Readily available lead concentration data from the Environmental Protection Agency data archives are limited to 2011 and 2012. Of the two monitoring sites in operation, the one between Globe and Miami at the intersection of U.S. 60 and State Route 188 (Apache Trail) indicated conditions well within the standard. The other site in Hayden showed exceedances of the standard for both years, hence the pending nonattainment area discussed earlier in this assessment.

Nitrogen Dioxide Concentrations

Along with volatile organic compound emissions, nitrogen oxides emissions lead directly to ozone production and, through the photochemical cycle, the generation of gaseous nitrogen dioxide. Of the gaseous and particulate nitrogen oxides, gaseous nitrogen dioxide is the only one regulated through a Federal ambient air standard. Health effects from exposure to elevated concentrations of nitrogen dioxide include inflammation of the airways for acute exposures and increases in the occurrence of bronchitis for children and other sensitive individuals chronically exposed to elevated nitrogen dioxide levels (WHO 2011). The closest nitrogen dioxide monitoring sites to the Tonto National Forest are in the Phoenix urban area and these show occasional exceedances of the one-hour standard. Transport trajectories in the daytime result in these ambient nitrogen dioxide concentrations reaching Tonto National Forest lands, especially those closest to urban Phoenix.

Visibility

Visibility has been recognized as an important value going back to the 1977 Clean Air Act amendments which designated visibility as an important value for Class I wilderness areas. Visibility refers to conditions that allow the appreciation of the inherent beauty of landscape features. This perspective takes into account the form, contrast, detail, and color of near and distant landscapes. Air pollutants (particles and gases) may interfere with the observer’s ability to see and distinguish landscape features.

Visibility data are presented for stations operated as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program sponsored by the Environmental Protection Agency and other government agencies. Visibility generally relates to the quality of visitors’ visual experience on the Tonto. Generally, the presence of air pollution degrades the visual quality of a particular scene. In the Clean Air Act, a national visibility goal was established to return visibility to natural background conditions no later than 2064. IMPROVE monitoring data track the quality of visibility conditions and trends in visibility data and are specific to the wilderness areas of interest.

The IMPROVE program has been monitoring visibility conditions in Class I wilderness areas in Arizona and nationwide since the late 1980s. Three IMPROVE monitoring sites are situated in the Tonto National Forest area: Tonto National Monument (TONT1), Sierra Ancha (SIAN1), and Queen Valley (QUVA1). Two of the monitoring sites, Tonto National Monument and Sierra Ancha, are located in the Tonto National Forest area; the third monitor is located in Queen Valley, on southwest border of Tonto.

IMPROVE monitors concentrations of atmospheric aerosols (sulfates, nitrates, etc.) and uses these data to assess light extinction, the degree to which light is absorbed, scattered, or both by air pollution. Visibility is normally expressed in terms of extinction or by using the deciview index, which is calculated from the measured extinction value. The deciview index represents a measure of change in visibility conditions which is typically perceptible to the human eye. A change in the range of 0.5 to 1.0 deciviews is generally accepted as being the limit of human perceptibility. Figure 81 illustrates the relationships among extinction, deciviews, and visual range.

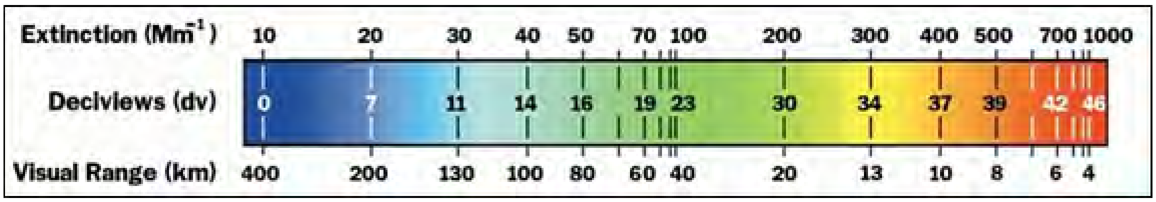


Figure 81. Relationship among extinction, deciview index, and visual range

Current Condition and Trend

Table 121 below, provides a summary of annual light extinction and reduced visibility in the Class 1 monitored areas. Assessed reduced visibility data (in deciviews) for the haziest days were obtained from the available years dating back to 2000 (IMPROVE 2014). Higher deciview values represent more degraded visibility conditions.

Table 121. Summary of IMPROVE visibility monitoring data, 20 percent worst-case days (deciviews)

Wilderness	IMPROVE Monitor	2000-04 Baseline	2005-09 Progress	2010-13	2064 Goal Natural Background
Tonto National Monument	TONT1	12.2	11.8	11.8	6.26
Sierra-Ancha	SIAN1	10.2	9.9	9.9	5.72
Queen Valley	QV	10.4	9.1	9.1	6.08

These numbers were averaged for baseline period (2000 to 2004), progress period (2005 to 2009), and for the last four years (2010 to 2013). The visibility condition representing the 2064 goal for achieving natural background is also shown. It is important to note that natural background numbers are different for each location. These data provide a measure of how much visibility improvement is required at each Class I area in order to achieve the 2064 national visibility goal.

These data show that for the haziest days, the general trend in visibility has been moderately improving. Table 121 also shows the level of visibility improvement through 2013 has been relatively modest compared to the visibility improvements needed by 2064 to achieve the goal of natural background conditions.

Atmospheric Deposition

Atmospheric deposition is the process by which airborne particles and gases are deposited on soil, water, vegetation, and other surfaces. Deposition can occur either through precipitation (rain, snow, cloud, fog), which is called wet deposition, or it can take place as a result of atmospheric processes such as adsorption, settling, or impaction, known as dry deposition. Total deposition is calculated by adding dry and wet deposition for each area.

Sulfur and nitrogen compounds are two of the most ecologically significant compounds that can be deposited onto the environment. Wet or dry deposition of sulfur and nitrogen compounds can result in acidification of fresh waters, eutrophication of aquatic ecosystems, and leaching of nutrients from soils. Deposition of these compounds can change terrestrial and aquatic species composition and abundance and injure high-elevation forests. (National Park Service 2006)**.**

Clean Air Status and Trends Network (CASTNET) is a monitoring network established to measure concentrations of key air pollutants involved in acid deposition. In Arizona, there are three CASTNET monitoring sites located on National Park Service lands at the Chiricahua National Monument and Petrified Forest and Grand Canyon National Parks. At each CASTNET monitoring site, samples are collected weekly, and dry deposition is calculated as a function of pollutant concentration and deposition velocity. (CASTNET fact sheet 2007)

Sulfur and Nitrogen Deposition

There are no CASTNET monitoring sites on the Tonto National Forest, so the sulfur and nitrogen deposition results for the Chiricahua National Monument are presented. Figure 82 illustrates both wet and dry deposition of sulfur as component of total sulfur deposition for this monitoring site. Trends for sulfur deposition show a steady decline in total sulfur deposition in the past two decades. Despite some annual fluctuations, total deposition of sulfur has decreased steadily since 1990 from 2.19 kilograms of sulfur per hectare to 0.91 kilograms of sulfur per hectare in 2012. Since 2000, the highest deposition has occurred in 2006 with 1.78 kilograms of sulfur per hectare. Seventy-four point five percent of total sulfur deposition in this location occurred by means of wet deposition in 2010 to 2012.

Wet sulfur deposition at this site warrants moderate concern since the ecosystem in the park is rated as having high sensitivity to the acidification effects of sulfur deposition. Due to the proximity of the Tonto National Forest to copper mining and smelting industries and elevated sulfur emissions in Gila County, sulfur deposition on the Tonto may warrant more concern.

Nitrogen deposition for the Chiricahua National Monument is presented in figure 83. This figure includes both wet and dry deposition of nitrogen as a component of total nitrogen deposition. According to the monitoring results, total deposition of nitrogen compounds has remained at 2.5 kilograms of nitrogen per hectare since 1990 with a slight increase in the early 2000s and the highest peak of 3.8 kilograms of nitrogen per hectare in 2006. The most recent nitrogen deposition data available for this site are for 2012 which shows 2.5 kilograms of nitrogen per hectare. Over 72 percent of total nitrogen is deposited through wet deposition.

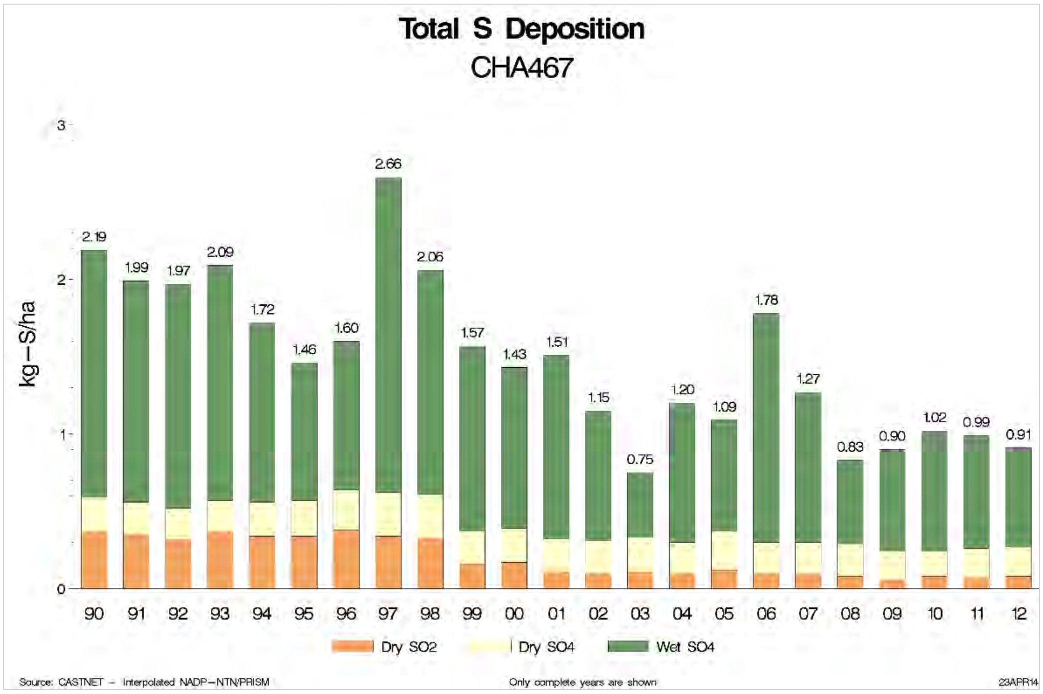


Figure 82. Total sulfur deposition (wet + dry) for Chiricahua National Monument (1990-2012)

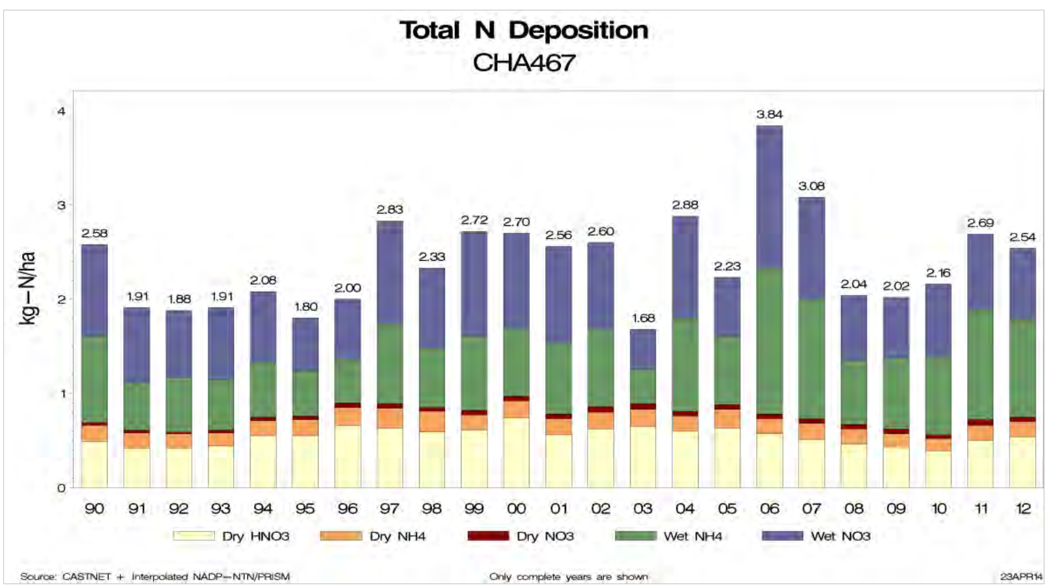


Figure 83. Total nitrogen deposition (wet + dry) at the Chiricahua National Monument (1990-2012)

Total nitrogen deposition at this site warrants moderate concern since the ecosystem is rated as having high sensitivity to nutrient enrichment effects of wet nitrogen deposition. Nitrogen deposition disrupts soil nutrient cycling and affects biodiversity of some plant communities.

Mercury Deposition

Mercury is a persistent bioaccumulative toxin that can stay in the environment for long periods, cycling between air, water, and soil. Mercury is deposited on the earth's surface through wet or dry deposition, and it can accumulate in the food chain and bodies of water. The atmospheric lifetime of mercury is up to two years, and it can last in soil as methyl mercury for decades. Mercury can bioaccumulate in organisms and biomagnify through the food chain in fish, humans, and other animals.

Mercury is emitted primarily by coal-fired utilities and enters surface waters as both wet and dry deposition. Wet deposition of mercury accounts for 50 to 90 percent of the inland aquatic mercury load, but the dry deposition rate on a forest canopy is higher than the wet deposition on terrestrial ecosystems.

Mercury is converted to methyl mercury by sulfur-reducing bacteria in aquatic sediments, and this form is present in fish. Methyl mercury is a potent neurotoxin that easily enters the blood stream and crosses the blood-brain barrier to reach the brain. Methyl mercury is of special concern for pregnant women since it can cross the placenta to reach the fetus. Both methyl mercury and mercuric chloride are listed as carcinogens by the Environmental Protection Agency (Mercury Deposition Network 2011).

In the United States, two networks measure and monitor mercury deposition. The Mercury Deposition Network, with over 100 monitoring sites in the U.S. and Canada, provides a long-term record of mercury concentration and deposition in precipitation. The Atmospheric Mercury Network studies the atmospheric mercury fraction of total mercury deposition and its dry deposition. Both networks are part of the National Atmospheric Deposition Program. Available data from these networks show the southwestern United States has a higher concentration of mercury due to coal-fired utilities and their limited levels of mercury pollution controls. However, due to the relatively low precipitation rates (except at higher elevations), the mercury from wet deposition is comparatively low. Figure 84 and figure 85 show total mercury concentration and deposition in the U.S. (Mercury Deposition Network 2011).

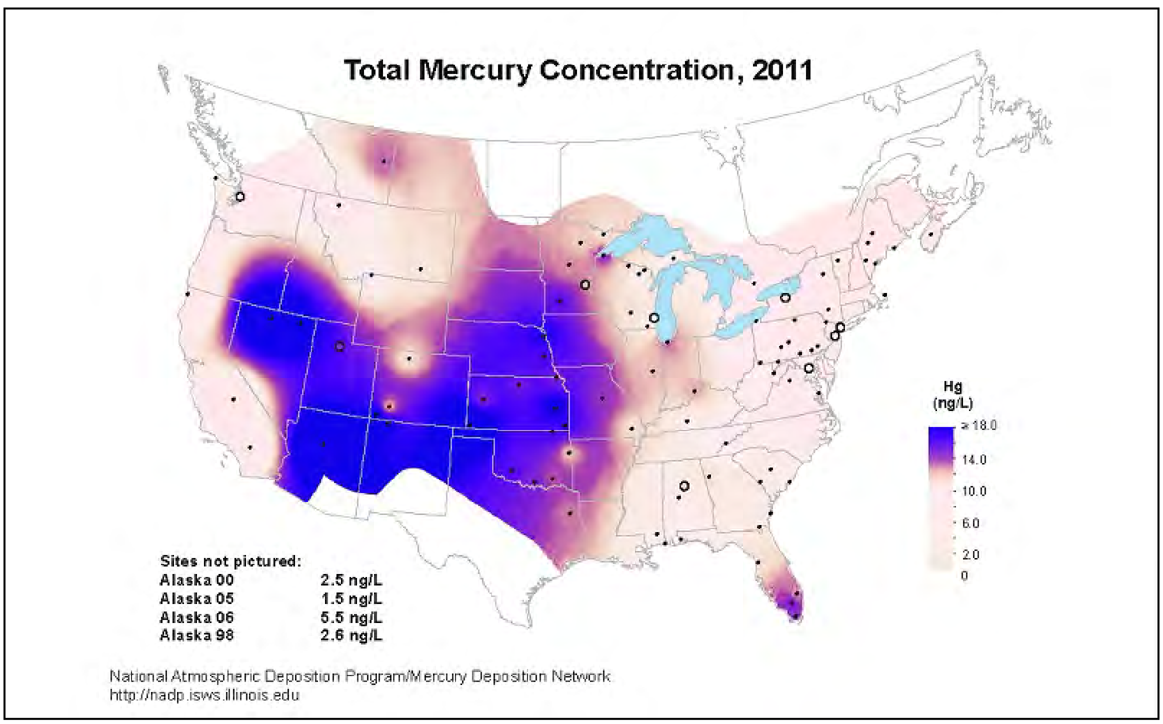


Figure 84. Total mercury concentration across the United States, 2011

While it is difficult to assess the current effects that mercury deposition is having on the Tonto National Forest, the general mercury deposition trend is expected to decrease over time. New regulatory controls should reduce the total mercury emissions over the next several years. In addition, sulfur emissions are also expected to decline, due to new sulfur fuel standards and pollution controls at the coal-fired utilities. The link between sulfur-reducing bacteria and biotic mercury concentrations has led researchers to establish that reductions in sulfur dioxide emissions and a resulting reduction in sulfate deposition will abate mercury concentrations in wildlife. As sulfates are reduced in aquatic systems, sulfur-reducing bacteria will reduce less sulfur, and this will lead to less inorganic mercury being methylated.

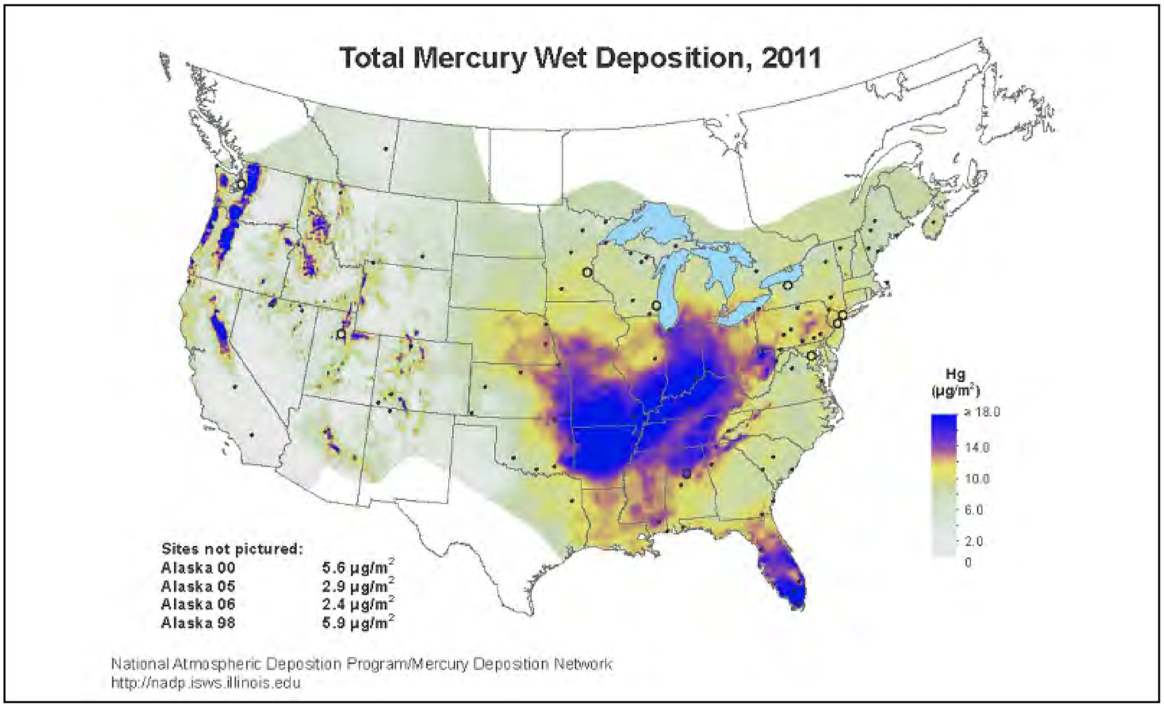


Figure 85. Total mercury wet deposition across the United States, 2011

Federal, State, and Tribal Implementation Plans

As stated previously, the Clean Air Act provides the basic framework for controlling air pollution, but the states are primarily responsible for implementing and enforcing Clean Air Act requirements. Within this framework, there are tools particularly relevant to protecting air quality related to national forests. Typically, air pollution that occurs off national forests is the primary concern for impacts on national forests. Pollution can result from either new or existing sources.

The primary tool for addressing air quality impacts from new sources is the Prevention of Significant Deterioration Program. The 1977 Clean Air Act amendments established the program to preserve the clean air usually found in pristine areas, while allowing controlled economic growth. The permitting program applies to new, major sources of air pollution or modifications to existing major sources which have the potential to emit certain amounts of air pollution regulated by the Environmental Protection Agency. The purpose of the Prevention of Significant Deterioration Program is to prevent violations of national ambient air quality standards and to protect the environment including visibility and air quality is pristine areas such as Class 1 wilderness areas managed by the Forest Service. The program can apply to noncriteria pollutants and can require analyses to assess the impacts of pollution on soils, vegetation, visibility, and water resources managed by the Forest Service.

For existing sources of air pollution, the Federal Regional Haze Rule (see following section) requires states to develop programs to assure reasonable progress toward meeting the national goal of preventing any future, and remedying any existing, impairment of visibility in mandatory Class I federal areas. The Regional Haze Rule addresses requirements for State implementation plans, plan revisions, and periodic progress reviews to address regional haze and achieve natural haze conditions in each Class I areas by 2064.

Regional Haze Rule

On July 1, 1999, the Environmental Protection Agency issued regional haze rules to comply with requirements of the Clean Air Act. Under 40 CFR section 51.309, the State of Arizona has developed a State implementation plan with long-term strategies out to the year 2064 to make "reasonable progress in improving visibility in Class I areas inside the State and in neighboring jurisdictions" (U.S. EPA 1999), and it focuses on anthropogenic sources of emissions. The Arizona State implementation plan outlines an enhanced smoke management plan meeting criteria in the Regional Haze Rule. The plan is a series of key policies and management practices to address visibility protection.

The key policy resulting from the enhanced smoke management plan pertaining to planned ignitions in Arizona is Arizona Revised Statute Title 18, chapter 2, article 15. This law regulates burning by Federal and State land managers, as well as burning by Tribal, private, and municipal burners who have a memorandum of understanding with the Arizona Department of Environmental Quality. This statute defines the request-and-approval process for all planned ignitions and provides the mechanisms for tracking emissions from those ignitions.

Enforcement of this statute is facilitated by the Smoke Management Group, housed at the Arizona Department of Environmental Quality. This group is comprised of a Forest Service employee, a Department of the Interior employee, and an Arizona Department of Environmental Quality employee. The group collects planned ignition requests daily and makes recommendations to the Arizona Department of Environmental Quality on requests to be approved based on forecasted meteorological conditions, number of concurrent planned and unplanned ignitions, residual pollutants from previous planned ignitions or other sources, and other factors. This group performs much of the work to track and summarize annual emissions from planned and unplanned ignitions to prepare required annual reports, and they monitor regional haze levels.

Grand Canyon Visibility Transport Commission – 1996 Findings and Recommendations

In 1990, amendments to the Clean Air Act under 40 CFR 51.309 established the Grand Canyon Visibility Transport Commission to advise the Environmental Protection Agency on strategies for protecting visual air quality on the Colorado Plateau. The Grand Canyon Visibility Transport Commission released its final report in 1996 and initiated the Western Regional Air Partnership, a partnership of State, Tribal, and Federal land management agencies to help coordinate implementation of the Commission's recommendations (Western Regional Air Partnership 1996 #453).

Issues addressed by the Grand Canyon Visibility Transport Commission and Western Regional Air Partnership are summarized below:

- Air pollution prevention
- Clean air corridors
- Stationary sources
- Areas in and near parks and wilderness areas
- Mobile sources
- Road dust
- Emissions from Mexico
- Fire

Forest Service Policy and Actions

Regional Forest Service air resource management staff act as the point of contact to receive and review permit applications filed with State and local regulatory agencies by new and modified emission sources and provide comments back to the State agency. Unless a specific issue arises, individual national forests are typically not responsible for conducting reviews of new and modified sources via the State-level air quality applications process. Forest Service regional office personnel provide air quality analysis to determine if proposed actions are likely to cause, or significantly contribute to, an adverse impact to visibility or other air quality related values within the National Forest System (USDA Forest Service 2012, no. 455).

The Forest Service lacks direct authority to control emissions from adjacent areas that affect its lands. The primary role of the air resource management staff is to provide information about potential impacts that could occur on National Forest System land, particularly in Class I areas. The primary tool Federal land managers use is the critical load concept described in the next section.

State Implementation Plans

The Arizona Department of Environmental Quality, Air Quality Division has issued a number of state implementation plans for nonattainment areas overlapping or adjacent to the Tonto National Forest. These plans include the following:

- Miami Sulfur Dioxide Nonattainment Area State Implementation and Maintenance Plan, 2002.
- Arizona State Implementation Plan – Miami PM10 nonattainment area, 2008
- Hayden Sulfur Dioxide Nonattainment Area State Implementation and Maintenance Plan, 2002.
- Payson Moderate Area Particulate Matter 10 Maintenance Plan and request for redesignation to attainment, 2002.

Critical Loads

Air pollution emitted from a variety of sources is deposited from the air into ecosystems. These pollutants may cause ecological changes, such as long-term acidification of soils or surface waters, soil nutrient imbalances affecting plant growth, and loss of biodiversity. The term critical load is used to describe the threshold of air pollution deposition below which harmful effects to sensitive resources in an ecosystem do not occur. Critical loads are based on scientific information about expected ecosystem responses to a given level of atmospheric deposition. For ecosystems already damaged by air pollution, critical loads help determine how much improvement in air quality would be needed for ecosystem recovery to occur. In areas where critical loads have not been exceeded, critical loads can identify levels of air quality needed to maintain and protect ecosystems into the future.

U.S. scientists, air regulators, and natural resource managers have developed critical loads for areas across the United States through collaboration with scientists developing critical loads in Europe and Canada. Critical loads can be used to assess ecosystem health, inform the public about natural resources at risk, evaluate the effectiveness of emission reduction strategies, and guide management decisions.

The Forest Service is incorporating critical loads into the air quality assessments performed for forest plan revision. There are no published critical loads in the southwest United States. For this assessment, national-scale critical loads were used to determine if critical loads were exceeded for nutrient nitrogen (Pardo et al. 2011), acidity to forested ecosystems (McNulty 2007), and for acidity to surface water (Lynch 2012). In addition, mercury deposition was analyzed based on data from the Mercury Deposition Network (MDN 2011); however, no critical loads have been developed for mercury on National Forest System land. Ozone deposition was not assessed due to the lack of data availability and analysis in the southwest United States. No critical loads have been developed for ozone on the Tonto National Forest.

Nitrogen Saturation and Eutrophication

Nitrogen air pollution can have an acidifying effect on ecosystems, as well as causing excess input of nitrogen into the ecosystem. In extreme cases, it can lead to nitrogen saturation. This excess nitrogen initially will accumulate in the topsoil and subsequently be leached into strata below, eventually reaching the groundwater table. While increased nitrogen may increase productivity in many terrestrial ecosystems (which are typically nitrogen limited), this is not necessarily desirable in protected ecosystems where natural ecosystem function is desired. Excess nitrogen can lead to nutrient imbalances, changes in species composition (trees, understory species, nonvascular plants (lichens), or mycorrhizal fungi), and ultimately declines in forest health.

Based on research by Pardo and others (2011), national-scale critical loads were developed for nitrogen deposition for lichen and herbaceous plants and shrubs. Pardo and others (2011) also developed critical loads for mycorrhizal fungi, forests, and nitrate leaching in soils, although they are not available for the Tonto National Forest.

In addition to developing critical loads, the same U.S. Department of Agriculture team (Pardo et al. 2011) produced a nationwide nitrogen deposition assessment through numerical modeling. These files have been examined and the information for the Tonto National Forest obtained. For the grids in the Tonto (some two hundred 4x4 kilometer grids), the nitrogen deposition values were limited to two different numbers: 3 kilograms of nitrogen per hectare per year and 8.4 kilograms of nitrogen per hectare per year. Earlier work with similar numerical models may provide a more realistic assessment of nitrogen deposition on the Tonto in contrast to the nearly uniform nitrogen deposition patterns indicated by the U.S. Department of Agriculture modeling.

This work acknowledges that, because of the arid climate on and around the Tonto National Forest, most of the nitrogen deposition is dry. Sources of gaseous nitrogen oxides (mostly nitric oxide, with much lesser amounts of nitrogen dioxide emissions) are dominated by gasoline and diesel fuel combustion in the on-road and nonroad mobile emission sectors. These two emission sectors include emissions from all vehicle travel on urban and rural roadways and from fuel combustion from activities such as heavy earthmoving and construction equipment, aircraft, lawn and garden equipment, and so forth (Maricopa County 2011). Prevailing daytime winds from the west and southwest transport these gaseous emissions eastward, out of the Phoenix metropolitan area and into the Tonto National Forest and points further east and north.

Investigators with the Central Arizona Phoenix – Long-term Ecological Research Project (CAP-LTER 2014) estimated both wet and dry nitrogen deposition through measurements and numerical modeling (Fenn 2003). The analysis area (11,000 square kilometers) consisted of all the urbanized and much of the surrounding agricultural and natural desert environments, including much of the Tonto National Forest.

Accounting for both gaseous and particulate nitrogen deposition (gaseous nitrogen oxides, ammonium ion, and particulate nitrate), and based on simulations for a single day in 1996, the dry deposition was estimated to be 13.5 kilograms of nitrogen per hectare per year for the urban core, 15.0 for the downwind desert, and 7.5 for the upwind desert. With wet deposition factored in from interpolated wet-bucket samples at eight sites, the total nitrogen deposition varied from 7 to 28 kilograms per hectare per year, with substantial maxima of fairly small spatial extent in the urban core and downwind regions that encompass the southern part of the Tonto. This suggests ecosystems of the Tonto are subject to nitrification from emissions of the upwind urban area, and in some localized regions of the Tonto National Forest, these deposition values can be elevated considerably above the published critical load values for these ecoregions (4 to 7 kilograms of nitrogen per hectare per year (Pardo et al. 2011)).

Lichens

Lichens, which enhance the biodiversity of ecosystems, are some of the most sensitive species to nitrogen deposition (Pardo et al. 2011). Unlike vascular plants, lichens have no specialized tissues to mediate the entry or loss of water or gases. They rapidly hydrate and absorb gases, water, and nutrients during periods of high humidity and precipitation. They dehydrate and reach an inactive state quickly, making them slow-growing and vulnerable to contaminate accumulation. As such, they are an important early indicator of impacts from air pollution.

Pardo and others (2011) used the major ecoregion types adapted from the Commission for Environmental Cooperation (CEC 1997); the Tonto is in the Temperate Sierras and North American Deserts ecoregions. The critical loads for lichens in these two ecoregions are based on research for North American Deserts and the Temperate Sierras, with minimum levels ranging from 3.0 to 4.0 kilograms of nitrogen per hectare per year (Pardo et al. 2011, Geiser et al. 2010).

Two lichen surveys were conducted in the Tonto National Forest in the early 1990s: one in the Mazatzal Wilderness Area and the other in the Superstition Wilderness Area (St. Clair and Newberry 1991). Although the relative abundance and diversity of the various lichen species appeared robust and unaffected by air pollution, elevated levels of sulfur were found in lichen tissues, indicating transported air pollution is reaching these lichen populations.

A later study based on collections from the Four Peaks, Salt River Canyon, Salome, and Hellsgate Wilderness Areas during the 2014 field season (St. Clair and Leavitt 2015) found somewhat elevated to elevated levels of nitrogen in all four areas, suggesting potential nitrogen-related air quality problems. Samples from Salome and Hellsgate Wilderness Areas also had elevated levels of manganese, suggesting potential manganese-related air quality problems in these areas.

Herbaceous Plants and Shrubs

Herbaceous plants and shrubs comprise the majority of the vascular plants in North America (USDA NRCS 2009). They are less sensitive to nitrogen deposition than lichens; however, they are more sensitive than trees due to rapid growth rates, shallow roots, and shorter life spans (Pardo et al. 2011). Herbaceous plants are the dominant primary producers, contributing significantly to forest litter biomass and biodiversity (Gilliam 2007). The shorter lifespan of some species can result in a rapid response to nitrogen deposition and rapid shifts (1 to 10 years) in community composition sometimes resulting in an increase in invasive species compared to native species (Pardo et al. 2011).

Acid Deposition

The potential for impacts from acid deposition on forests has been recognized for more than 30 years in the United States. Research has shown that nitrogen and sulfur deposition has resulted in acidifying effects. The acidification has had negative impacts on ecosystem health, including impacts to aquatic resources, forest sustainability, and biodiversity (McNulty 2007). Acidifying effects can lead to mortality of tree species, reduced forest productivity, reduced biological diversity, and increased stream acidity (Driscoll 2001).

The following section presents critical acid load for soils and surface water on the Tonto. McNulty estimated critical loads and exceedances for forested soils across the United States (McNulty 2007). The surface water critical acid loads were based on research from Lynch (2012).

Soils

Many factors contribute to an exceedance of critical acid loads in forested ecosystems, including the composition of the soil, how weathered it is, the amount of organic matter present, and the amount of base cations (for example, calcium, potassium, magnesium, and sodium), which all play a role in how well the soil is buffered against acid deposition (how well the soil can neutralize the acid). Sandy soils are typically low in base cations, making them more vulnerable to acid deposition.

The types of tree species present are also important due to the rates at which they consume nitrogen and due to their base cations which can either counteract the effects of acid deposition or reduce a soil’s buffering capacity. In conifer forests, as the needles break down, the soil is naturally acidified, which can increase the system’s vulnerability to acidification.

The rate at which atmospheric sulfur and nitrogen compounds reach the ground through either wet or dry deposition is important. The extent of this deposition depends on the nature, location, and atmospheric chemistry during transport of the emissions adding these compounds to the airshed. Elevation also plays a role, since more precipitation tends to occur at higher elevations, increasing the rate of wet deposition above that of the lower-elevation, drier landscapes.

Estimates that factor all the parameters described above show there are no exceedances of acid critical loads on the Tonto. This is primarily a result of the generally low concentrations of acidic gases in the airsheds of Arizona and the western United States. “Generally” is a critical term for south-central Arizona, because of the copper mining, smelting, and refining activities that emit major amounts of gaseous sulfur dioxide. Elevated sulfur dioxide concentrations have been documented for four decades in this region; it is possible, but not demonstrated, there could be localized hotspots of deposition in or near the Tonto. If this is the case, then the more national estimates, such as those in figure 86, may not include these relatively small, isolated depositional environments.

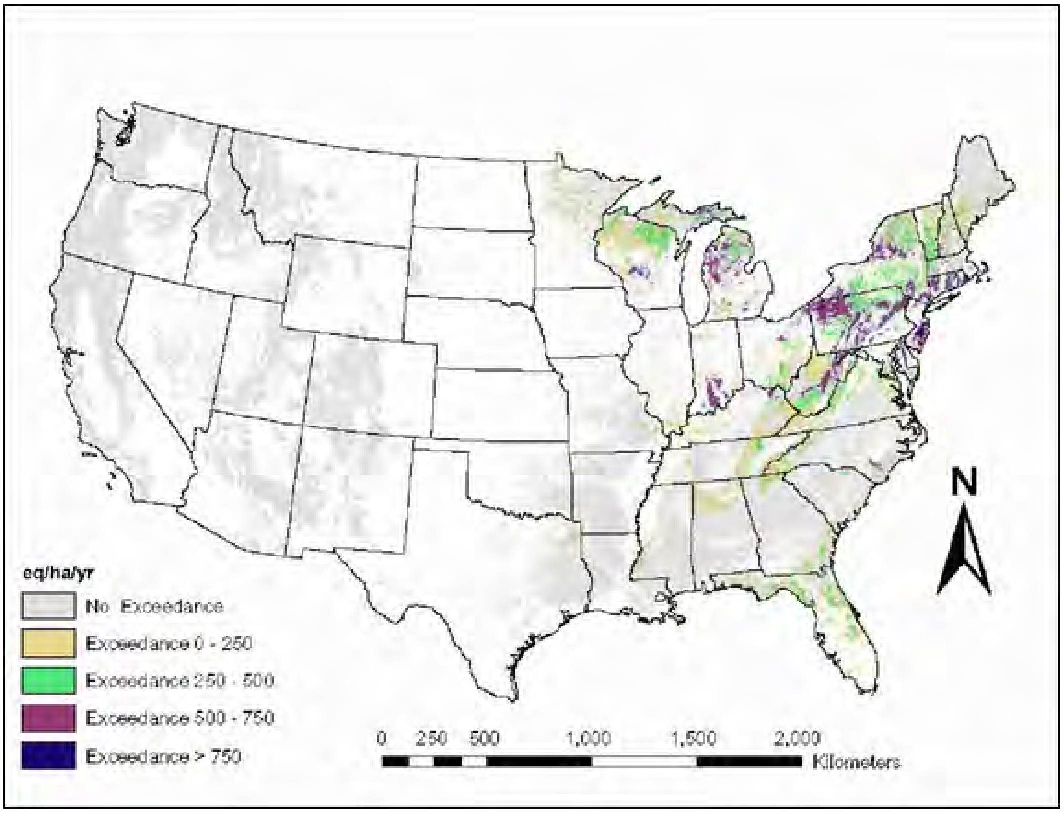


Figure 86. Average annual exceedance of the critical acid load for forest soils

Surface Water Impacts

Stream and lake acidification can result from the deposition of acidic gases, which can reduce the pH of surface water resulting in reduced diversity and abundance of aquatic species. As described in the previous section, many of the same factors make aquatic ecosystems susceptible to the effects of acid deposition. Surface water acidification begins with acid deposition in adjacent terrestrial areas (Pidwirny 2006) and the system's ability to neutralize the acid before it leaches into the surface water.

Potential acidification of lakes and streams by deposition is one consideration, but of paramount importance for water quality is the direct and indirect discharge of acid mine drainage into the surface waters and groundwater in and near the Tonto. Streams, such as Pinto and Pinal Creeks, have received acidic discharges from both historic and present mining operations, including the Pinto Valley Mine lately operated by BHP Copper, Inc., which is virtually surrounded by the Tonto. Pinal Creek served for decades as a discharge area for leaching operations from numerous copper mining companies in the Miami-Globe area.

The Arizona Department of Environmental Quality's Water Quality Division, through its aquifer protection program and various water assessment section programs, restricts and monitors present discharges and compels mining companies to build their facilities with potential discharges to the best and highest design and engineering standards. Nonetheless, localized surface and groundwater quality problems have been monitored, studied, and documented, and remedial actions for cleanup have been mandated and carried out. It should be recognized, however, that these surface water and groundwater problems take place in a small portion of the Tonto in its districts south of the Salt River and its four reservoirs.

There are no critical loads available for the Tonto National Forest to assess acid deposition to surface water. A national analysis was conducted with the steady-state water chemistry model, which employs a mass-balance approach to assess acid critical loads for surface water (Lynch 2012). This assessment did not include any surface water sites on the Tonto. Every two years, the Arizona Department of Environmental Quality submits an assessment of the surface waters to the Environmental Protection Agency as required by the Clean Water Act. Based on the current list of impaired waters in Arizona, there have been, and probably still are, certain reaches of streams and certain aquifers with acidified water (ADEQ 2011b) in the Tonto National Forest – a consequence of direct and indirect discharges from historic and current mines, not from atmospheric deposition.

Ozone

Ground-level ozone interferes with the ability of plants to produce and store food, which makes them more susceptible to disease, insects, other pollutants, drought, and higher temperatures. Some plants have been identified as particularly sensitive to the effects of ozone and are reliable indicators of toxic levels of the pollutant on plant growth.

Ozone damages the appearance of leaves on trees and other plants. The most common visible symptom of ozone injury on broad-leaved bioindicator species is uniform interveinal leaf stippling, also known as leaf spotting and discoloration. As a gaseous pollutant, ozone enters the stomata of plant leaves through the normal process of gas exchange, damaging the tissue. Elevated levels of ozone have been monitored at the three IMPROVE sites in the Tonto National Forest and at sites on the eastern and northeastern fringes of the Phoenix metropolitan area (Section 4.2.1). To our knowledge, no assessment of the Tonto's vegetation has been conducted to investigate the deleterious effects of ozone. Such an assessment would most likely need to concentrate on the coniferous forests of the Tonto's higher elevations, the botanical ecosystems perhaps most susceptible to ozone damage and where most of the relevant research has been conducted throughout the country.

Uncertainty

The reliability of, and confidence in, any assessment, including this air assessment for the Tonto, depends on the representativeness, duration, precision, and accuracy of the relevant measurements. The more direct measurements are taken over time, and the more these measurements can be proven reliable by quality assurance and quality control programs and protocols, the greater the level of confidence in the assessment. In the absence of direct measurements or where direct measurements can be interpolated to greater spatial scales, modeled data can help assess the relative risk of ecosystems to air pollution. Numerically interpolated or modeled concentrations and deposition patterns, however descriptive and necessary, introduce a greater degree of uncertainty in the assessment. To understand the level of confidence in the modeled results, it is important to understand the assumptions in the models and how they perform in a given environment. In this case, how do they perform assessing the potential impacts that air pollution has on various indicators such as lichens on the Tonto National Forest?

Direct measurements of ambient air quality and visibility are abundant. Water quality surveys and investigations have taken place intermittently in Tonto National Forest streams and lakes. Nonetheless, there have been few studies performed on the Tonto to directly measure the effects of air pollution on forest health. The modeled results indicate lichens and, to a lesser degree, herbaceous plants and shrubs, are at risk of being impacted by nitrogen deposition. There is a fair amount of uncertainty with these estimates, however. The critical loads were developed based on lichen studies in western Oregon and Washington for the Temperate Sierras and based on research in Hells Canyon for the North American Desert ecoregion (Pardo et al. 2011). In addition, atmospheric nitrogen deposition estimates and critical loads are influenced by several other factors, including the difficulty of quantifying dry deposition on complex mountainous terrain in arid climates with sparse data (Pardo et al. 2011), all of which are significant factors on the Tonto. In summary, uncertainty has to be considered fairly high with regard to the critical load estimates employed in this assessment; therefore, only a moderate level of confidence in applying these critical loads to the Tonto National Forest can be supported.

Summary of Condition, Trend, and Risk

Air quality on or near the Tonto National Forest is within regulatory levels for national ambient air quality standards for some air pollutants. Exceedances, violations, or both of air quality standards for ozone, particulate matter 10, lead, and sulfur dioxide have been documented. Carbon monoxide and nitrogen dioxide meet their regulatory standards. Air pollutant trends based on projected emission inventories and ambient concentrations appear steady or improving for most pollutants, as is the case for visibility.

Reducing particulate matter in arid climates remains a daunting challenge. Particulate matter leads directly to visibility degradation. Urban, agricultural, and recreational activities; climate change; and drought generate particulate emissions upwind from, and in, the Tonto. Particulate matter from urban, agricultural, and recreational activities are transported from the Phoenix area into the Tonto National Forest.

Prescribed and wildfires in and near the Tonto National Forest produce smoke and gaseous air pollutants that degrade air quality and visibility and adversely affect respiratory health. These fires show signs of becoming more important sources in the coming years. Prescribed fires are meticulously planned and regulated (for all state and national forests within the state) by the Arizona Department of Environmental Quality. Conducted in designated areas during times of the day when smoke dispersion is at its maximum, these burns produce smoke that the foresters and regulators strive to keep away from populated areas such as villages and towns. Wildfires, particularly the larger and more severe ones, produce smoke and present imminent danger to homes and residents that often result in forced evacuations.

The following tables summarize conditions, trends, and reliability of assessment for various air quality indicators.

Table 122. Summary of conditions, trends, and reliability of assessment for pollutants relative to their national ambient air quality standards.

Air Quality Measure	Current Conditions	Trend	Reliability
Carbon monoxide	Excellent	Steady	High
Nitrogen dioxide$_2$	Good	Improving	High
Sulfur dioxide	Fair	Stable	High
Lead	Fair	Stable	High
Ozone	Fair	Stable	High
Particulate matter 2.5	Good	Stable to Declining	High
Particulate matter 10	Fair	Stable to Declining	High

Table 123. Summary of conditions, trends, and reliability of assessment for visibility relative to 2064 regional haze goal

Air Quality Measure	Current Conditions	Trend	Reliability
Visibility	Good	Stable to Improving	High

Table 124. Summary of conditions, trends, and reliability of assessment for critical loads (deposition), nitrogen eutrophication

Air Quality Measure	Current Conditions	Trend	Reliability
Lichens	Fair	Unknown	Low
Herbaceous Plants & Shrubs	Unknown	Unknown	Low
Mycorrhizal Fungi	Unknown	Unknown	NA
Forests	Unknown	Unknown	NA
Nitrate Leaching	Unknown	Unknown	NA

Table 125. Summary of conditions, trends, and reliability of assessment for critical loads, acid deposition

Air Quality Measure	Current Conditions	Trend	Reliability
Soils	Good	Improving	Low
Surface Water	Good	Steady	Low

Table 126. Summary of conditions, trends, and reliability of assessment for critical loads, other deposition

Air Quality Measure	Current Conditions	Trend	Reliability
Mercury	Potentially at risk	Improving	Low
Ozone	Fair	Steady	High

There is some indication current levels of nitrogen deposition have exceeded critical loads and are significant enough to have affected lichen diversity and community structure and, to a lesser degree, herbaceous plants and shrubs. However, these results were based on modeled critical loads and have not been verified on the Tonto National Forest. The rate of nitrogen deposition, which can affect forest health, appears to be decreasing based on projected emissions at the state level.

Modeled results also indicate levels of acid gases are not significant enough to result in impacts to either soils or surface water. There are no direct measurements on the Tonto National Forest that indicate otherwise.

There is some indication that mercury deposition at higher elevations on the Tonto may be significant, but there are no studies to verify impacts. Atmospheric mercury, based on regional emissions, is also expected to decrease.

Key Message

Air quality and the values dependent on air quality on the Tonto National Forest are generally in fair to good condition with a stable trend; however, ambient air quality conditions associated with particulate matter show a stable to declining trend. Visibility and air quality may decline if particulate matter increases, likely a result of larger, more severe wildfires and increases in fugitive dust as the effects of climate change are realized.

Chapter 9. Climate Change

Although regional climates persist for centuries, they do change, and vegetation responds on a similar scale (Delcourt et al. 1983). The ecosystems we see today are the products of species evolution and migration over time on a constantly shifting landscape driven by climate. Climates change at a variety of scales. Long-term, persistent trends in temperature and humidity determine the extent and location of various life zones, the elevation at which one biotic community replaces another. Short-term fluctuations, in the order of years to decades, determine drought cycles, fire frequencies, and pulses of tree reproduction. The Southwest is strongly influenced by oscillation in the Pacific ocean-atmosphere system. El Niño years bring increased annual precipitation but less rain in the summer, and years of La Niña bring the opposite.

Two most important factors for determining fire regimes are vegetation type (or ecosystem) and weather and climate patterns. Fire history provides evidence of past relationships between fire and climate. Evidence makes it clear that changing climate will profoundly affect the frequency and severity of fires, and vegetation ultimately, in many regions and ecosystems in response to factors such as earlier snowmelt and more severe or prolonged droughts (Westerling et al. 2006; Bowman et al. 2009; Flannigan et al. 2009). Changing climate will also alter the growth and vigor of existing vegetation, with resulting changes in fuel structure and dead fuel loads. For these reasons, land managers need to assess ongoing and potential effects of climate change and coordinate a response for ecosystems, species, and human communities.

The Nature Conservancy, the Integrated Landscape Assessment Project, and others have developed assessments, tools, and methods for evaluating vulnerability for key ecological components. Based on the anticipated effects of climate change on site potential, the vulnerability of individual plant communities is assessed and scored as low, moderate, high, or very high, according to the degree by which their climate envelopes are exceeded under future climate projections. Climate envelopes were developed for each major ecological response unit on the Tonto National Forest using contemporary climate data for Arizona and New Mexico. Ecological response units were segmented based on site potential, and each segment was assigned a vulnerability score based on the projected departure in future climate from the current climate envelope of the given ecological response unit. Departure scores were then averaged across the plan scale, by ecological response unit within the plan scale, and by ecological response unit at the local scale (additional detail found in Triepke 2015).

Vulnerability reporting: This assessment categorizes climate change vulnerability based on individual plant communities and the projected difference between contemporary climate envelopes and projected climate conditions. Four categories of vulnerability are reported: low, moderate, high, and very high.

Uncertainty reporting: Future climate projections based on different general circulation models provide somewhat different values, reflecting uncertainty with a given vulnerability prediction for some ecological response units in some areas. To address this concern, the climate change vulnerability assessment provides a measure of uncertainty, which represents the degree of disagreement between different general circulation models, within a given emission scenario. Three general circulation models were used to assess uncertainty: Third Generation Coupled Global Climate Model; Hadley Centre Coupled Model, version 3; and Geophysical Fluid Dynamics Laboratory Circulation Model. Uncertainty is reported using a simple agreement process and categories.

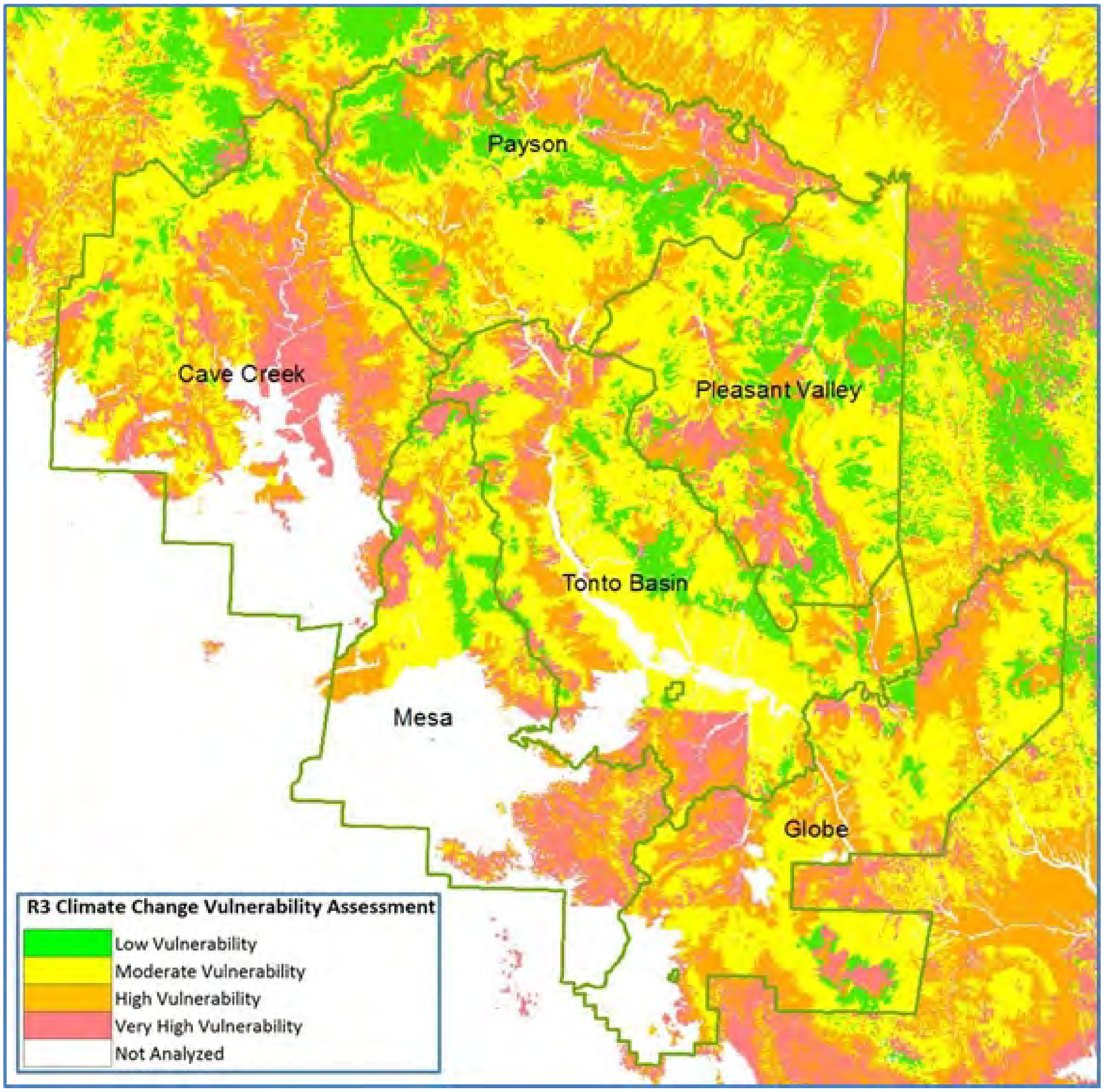


Figure 87. Patterns of climate change vulnerability on the Tonto National Forest and surrounding lands of central Arizona according to the climate change vulnerability assessment. The Tonto National Forest and its ranger districts are delineated with dark green borders.

Vulnerability to climate change indicates a higher potential for significant alteration of structure, composition, or function within the ecological response unit. The vulnerability of a point on the landscape is a function of (1) the breadth of the current climate envelope for the ecological response unit, (2) the position of the location in climate envelope space, and (3) the projected magnitude of projected climate change at the location. Therefore, high vulnerability may indicate the area is on a marginal limit of current climate, it may indicate climate in the area is predicted to shift far from the current envelope for the ecological response unit, or a combination of both.

Table 127 through table 138 show climate change vulnerability and uncertainty at the Tonto National Forest scale, and ecological response unit scales.

Table 127. Climate change vulnerability and uncertainty at the plan unit scale (Tonto National Forest)

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	6%	5%	0%	11%
Moderate Vulnerability	1%	28%	21%	50%
High Vulnerability	1%	25%	0%	26%
Very High Vulnerability	11%	2%	0%	13%
All Ecosystems Total	18%	60%	21%	

Table 128. Climate change vulnerability and uncertainty for the Interior Chaparral ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	9%	9%	**0%**	**18%**
Moderate Vulnerability	0%	29%	**28%**	**58%**
High Vulnerability	0%	21%	**0%**	**21%**
Very High Vulnerability	2%	2%	**0%**	**4%**
Interior Chaparral Total	**11%**	**61%**	**28%**	

Table 129. Climate change vulnerability and uncertainty for the Juniper Grass ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	0%	**0%**	**0%**
Moderate Vulnerability	0%	3%	**0%**	**3%**
High Vulnerability	1%	0%	**0%**	**1%**
Very High Vulnerability	96%	0%	**0%**	**96%**
Juniper Grass Total	**96%**	**3%**	**0%**	

Table 130. Climate change vulnerability and uncertainty for the Mixed Conifer - Frequent Fire ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	0%	**0%**	**0%**
Moderate Vulnerability	0%	6%	**1%**	**7%**
High Vulnerability	11%	20%	**0%**	**31%**
Very High Vulnerability	63%	0%	**0%**	**63%**
Mixed Conifer - Frequent Fire Total	**73%**	**26%**	**1%**	

Table 131. Climate change vulnerability and uncertainty for the Madrean Encinal Woodland ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	1%	**0%**	**1%**
Moderate Vulnerability	0%	30%	**10%**	**40%**
High Vulnerability	7%	28%	**0%**	**35%**
Very High Vulnerability	24%	0%	**0%**	**24%**
Madrean Encinal Woodland Total	**31%**	**59%**	**10%**	

Table 132. Climate change vulnerability and uncertainty for the Pinyon-Juniper Evergreen Shrub ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	8%	2%	0%	**10%**
Moderate Vulnerability	2%	31%	16%	**49%**
High Vulnerability	0%	28%	0%	**28%**
Very High Vulnerability	9%	4%	0%	**13%**
Pinyon-Juniper Evergreen Shrub Total	**19%**	**65%**	**16%**	

Table 133. Climate change vulnerability and uncertainty for the Pinyon-Juniper Grass ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	11%	20%	0%	**31%**
Moderate Vulnerability	0%	32%	27%	**58%**
High Vulnerability	0%	10%	0%	**10%**
Very High Vulnerability	0%	0%	0%	**0%**
Pinyon-Juniper Grass Total	**11%**	**62%**	**27%**	

Table 134. Climate change vulnerability and uncertainty for the Pinyon-Juniper Woodland ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	0%	0%	**0%**
Moderate Vulnerability	0%	0%	1%	**1%**
High Vulnerability	0%	0%	0%	**0%**
Very High Vulnerability	99%	0%	0%	**99%**
Pinyon-Juniper Woodland Total	**99%**	**0%**	**1%**	

Table 135. Climate change vulnerability and uncertainty for the Ponderosa Pine - Evergreen Oak ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	1%	0%	**1%**
Moderate Vulnerability	0%	13%	16%	**29%**
High Vulnerability	6%	40%	0%	**46%**
Very High Vulnerability	24%	0%	0%	**24%**
Ponderosa Pine - Evergreen Oak Total	**30%**	**54%**	**16%**	

Table 136. Climate change vulnerability and uncertainty for the Ponderosa Pine Forest ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	0%	0%	**0%**
Moderate Vulnerability	0%	29%	5%	**34%**
High Vulnerability	9%	7%	0%	**16%**
Very High Vulnerability	50%	0%	0%	**50%**
Ponderosa Pine Forest Total	**59%**	**36%**	**5%**	

Table 137. Climate change vulnerability and uncertainty for the Semi-Desert Grassland ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	2%	4%	0%	**6%**
Moderate Vulnerability	0%	20%	18%	**38%**
High Vulnerability	0%	37%	0%	**37%**
Very High Vulnerability	13%	6%	0%	**19%**
Semi-Desert Grassland Total	**15%**	**66%**	**18%**	

Table 138. Climate change vulnerability and uncertainty for the Sonora-Mojave Mixed Salt Desert Scrub ecological response unit

Vulnerability Category	Low Uncertainty	Moderate Uncertainty	High Uncertainty	Total Uncertainty
Low Vulnerability	0%	0%	0%	**0%**
Moderate Vulnerability	0%	0%	0%	**0%**
High Vulnerability	0%	100%	0%	**100%**
Very High Vulnerability	0%	0%	0%	**0%**
Sonora-Mojave Mixed Salt Desert Scrub Total	**0%**	**100%**	**0%**	

While there is moderate to high uncertainty among model predictions, 39 percent of the Tonto National Forest has high to very high vulnerability to climate change and 50 percent has moderate vulnerability. The percent of acres classified as low vulnerability to climate change does not exceed 11 percent for any given ecological response unit in the low uncertainty category. This is also true when analyzed across all ecosystems on the Tonto when summed across low, moderate, and high uncertainty categories. Low to mid elevations have a higher sensitivity to climate change than higher elevations (figure 87).

The woodlands have the highest vulnerability to climate change effects on the Tonto National Forest. Pinyon-Juniper Woodland and Juniper Grass ecological response units have the highest risk; nearly all acres are in the very high vulnerability category. Additionally, both of these ecological response units have greater than 96 percent certainty or agreement between global circulation models. While current and projected conditions show low seral state departure, climate change will likely push these systems into moderate or high departure. Pinyon-Juniper Woodlands, a key Southwestern vegetation type, are clearly water-limited systems and pinyon-juniper ecotones are sensitive to feedbacks from environmental fluctuations. Existing canopy structure may provide trees with a buffer against drought; however, severe, multi-year droughts may overwhelm local buffering and periodically cause dieback of pinyon pines. The dieback during the early 2000s was historically unprecedented in its combination of fire suppression influence, low precipitation, and high temperatures. Increased drought stress via warmer climate was the predisposing factor, and pinyon pine mortality and fuel accumulations were inciting factors (USDA FS 2010c). Additionally, ecosystem change may arise from large-scale severe fires that lead to the colonization of invasive species, which further compromises the ability of pinyon pines to re-establish.

Of the forested ecological response units, 94 percent of the Mixed - Conifer Frequent Fire ecological response unit has high to very high vulnerability with a moderate to high agreement between the general circulation models (73 percent in the low uncertainty category). For the Ponderosa Pine Forest ecological response unit, 66 percent has high to very high vulnerability with some disagreement between models (42 percent between moderate and high uncertainty categories); however, none of the models predict low vulnerability to climate change effects. For the Ponderosa Pine - Evergreen Oak ecological response unit, 70 percent has high to very high vulnerability with much less agreement between models (only 30 percent in the low uncertainty category); however, only 1 percent of acres were classified as having low vulnerability to climate change effects. The effects of climate change, along with the high fuel loads, closed canopies, stressed conditions, and large wildfires in these ecological response units, will continue to put the ecosystems at high risk.

For other ecological response units, such as the Pinyon-Juniper Grass, Pinyon-Juniper Evergreen Shrub, Interior Chaparral, and Semi-Desert Grassland, vulnerability to climate change and certainty and agreement among models is less clear (acres are more evenly distributed among vulnerability categories). However, these ecological response units show more acres in the moderate to high vulnerability categories than the low vulnerability category.

Long-term and short-term climate variability may cause shifts in the structure, composition, and functioning of these ecosystems, particularly in the fragile boundaries of the semiarid regions. These areas already contain plants, insects, and animals highly specialized and adapted to the landscape. A changing climate of wetter, warmer winters, and overall temperature increases would alter species range, type, and number throughout the Southwest. Responding differently to shifts in climate, the somewhat tenuous balance among ecosystem components will also change. As phenology is altered, the overall effects among interacting species are difficult to predict, particularly given the rate of climate change and the ability of symbionts to adapt. Because the health of the ecosystem is a function of water availability, temperature, carbon dioxide, and many other factors, it is difficult to accurately determine the extent, type, and magnitude of ecosystem change under future climate scenarios. Yet, should vegetation cover and moisture exchanging properties of the land change, important local and regional climate characteristics such as albedo (amount of radiation reflected by a surface), humidity, wind, and temperature will also change, with potential compounding negative effects to vegetation (Sprigg et al. 2000).

Chapter 10. Carbon Stocks

The emission of greenhouse gases by human activities and natural processes contributes to the warming of the Earth's climate. Warming could have significant ecological, economic, and social impacts at regional and global scales (IPCC 2007). In 2005, U.S. forests were estimated to be sequestering nearly 220.5 million tons of carbon (Cameron et al. 2003), to suggest that forests and woodlands of the Southwest could have a significant role to play in the sequestration of carbon and climate change mitigation. The U.S. Forest Service has directed a baseline assessment of carbon stocks as part of the forest plan assessment process (36 CFR 219.6(b)(4)).

Below, we consider the major carbon components of Southwest ecosystems including biomass, carbon emissions, and soil organic carbon. Some estimates are provided for biomass and soil carbon on the Tonto National Forest. For the moment, the carbon emissions component has been characterized by using a case study synthesis from the Apache-Sitgreaves National Forests. We acknowledge the description of other carbon components, such as forest products, would provide a fuller accounting of carbon stocks and flux. For the time being, inclusion of the major components of biomass, emissions, and soil carbon will suffice for strategic purposes of forest planning.

Biomass (Vegetative Carbon)

Vegetative biomass serves an integral component in forest carbon cycles. Forest vegetation, through the process of photosynthesis, converts atmospheric carbon dioxide to carbohydrates (referred to as carbon fixation). These carbohydrates (sugars) are used by plants to grow both aboveground biomass, in the form of stems and leaves, and belowground biomass, in the form of roots and tubers. Conversely, dead plant material slowly releases carbon into the atmosphere as it decomposes. Total carbon stored in vegetative biomass is referred to as the biomass carbon stock, and this value changes through time.

The primary influences on biomass carbon stock are plant growth (primary productivity) which serves to increase biomass carbon stock, decay and decomposition which slowly decreases biomass carbon stock, and disturbance in the form of fire and harvest. Wildland fire provides a major source of carbon emissions in a forest setting and is discussed in detail in the carbon emissions section on page 460. Biomass harvest plays a varying role in carbon emissions, depending largely on the use of the wood products. Wood products used as saw timber in construction tend to provide long-term carbon storage with slow release, while wood products used as fuelwood and burned for heat provide increased carbon emissions into the atmosphere. As forest and grassland ecosystems are constantly changing through natural succession and disturbance, biomass carbon stock also changes through time. This section will focus on biomass carbon stocks over time on lands of the Tonto National Forest. For the purpose of this section, biomass carbon stock includes aboveground live biomass, standing dead biomass, downed woody debris, litter and duff, and belowground live biomass (belowground nonliving plant material is considered in soil organic carbon).

Current Conditions: Biomass Carbon Quantities

The Tonto National Forest can be stratified into eleven major ecosystem types referred to as ecological response units (Wahlberg et al. 2013). The Tonto has several minor types, including two (both subclasses of the Mojave-Sonoran Desert Scrub ecosystem) listed in table 139: Creosote Bursage Desert Scrub and Sonoran Mid-Elevation Desert Scrub. Each ecological response unit contributes differently to carbon stocks and their flux based on its spatial extent, vegetation community composition and structure, and ecosystem dynamics. Generally speaking, relative contributions to carbon stocks are lowest in desert and grassland ecological response units, with increasing contributions by shrubland, woodland, and forest ecological response units, respectively.

Table 139. Major ecological response units on the Tonto National Forest in acres and percent

System Type	Ecological Response Unit and Code	Acres	Percent
Desert	Creosote Bursage Desert Scrub (CB)	69,143	2.5%
Desert	Sonoran Mid-Elevation Desert Scrub (SOS)	114,344	4.2%
Desert	Sonoran Paloverde Mixed Cactus Desert Scrub (SP)	624,611	22,8%
Grassland	Semi-Desert Grassland (SDG)	346,707	12.6%
Shrubland	Interior Chaparral (IC)	294,352	10.7%
Woodland	Pinyon-Juniper Grass (PJG)	80,699	2.9%
Woodland	Juniper Grass (JUG)	416,445	15.2%
Woodland	Pinyon-Juniper Evergreen Shrub (PJC)	338,098	12.3%
Woodland	Pinyon-Juniper Woodland (PJO)	55,963	2.0%
Woodland	Madrean Encinal Woodland (MEW)	93,769	3.4%
Forest	Ponderosa Pine - Evergreen Oak (PPE)	217,838	7.9%
Forest	Ponderosa Pine Forest (PPF)	37,471	1.4%
Forest	Mixed Conifer – Frequent Fire (MCD)	51,990	1.9%
(not applicable)	Totals	2,741,430	100.0%

The figures and tables presented in this section represent carbon stocks for current conditions and reference conditions. For select ecological response units, they also present carbon stocks modeled for future conditions under current management intensities. Carbon stock values are presented below both by ecological response units and collectively for the Tonto National Forest.

For each seral (or successional) state in each ecological response unit, we have assigned carbon stock coefficients based on information from the scientific literature and web resources or from forest inventory and analysis sample data and the carbon submodel of the Forest Vegetation Simulator (Weisz et al. 2010) – Fire and Fuels Extension (Johnson et al. 2015).

Scientific literature and web resources were used for desert, grassland, and shrubland ecological response units (Boyd and Bidwell 2001; Brooks and Pyke 2001; Scott and Burgan 2005; USDA Forest Service 2012). Forest inventory and analysis data and Forest Vegetation Simulator were used for woodland and forest ecological response units.

Carbon stock totals for each ecological response unit are derived by multiplying the current or forecasted total acreage in each seral state by the corresponding carbon coefficient and summing across all seral states. The current Tonto National Forest carbon stock overall is about 106 percent of that present in reference (historic) conditions. While this increase suggests little change over reference conditions, a more complete picture can be drawn by looking at relative contributions from individual ecological response units.

As illustrated in table 140 and figure 88, the biomass carbon stock has decreased somewhat in shrubland (Interior Chaparral ecological response unit) and two woodland ecological response units (Juniper Grass and Pinyon-Juniper Woodland), while increasing somewhat in the grassland

(Semi-Desert Grassland ecological response unit) and one woodland (Madrean Encinal Woodland ecological response unit) system. The most dramatic differences are seen in two forest systems: the Ponderosa Pine - Evergreen Oak ecological response unit, which now holds over twice the biomass present in reference conditions and the Ponderosa Pine Forest ecological response unit, which contains almost 50 percent more carbon than in reference. For the most part, carbon increases coincide with fire-adapted (frequent fire) ecosystems, while decreases are coincident with those systems of low to moderate fire frequency. Carbon increases in fire-adapted types are presumably associated with land management patterns, including the exclusion of fire over the past 50 years, and limited harvest of trees in the recent years and decades. The reduction in woodland biomass may be associated, at least in part, with chaining and other modifications that resulted in overstory removal. In the table, shading in orange indicates an increase in carbon stock, and shading in blue indicates a reduction in carbon stock. In both cases, deeper hues reflect greater departure from reference conditions.

Table 140. Biomass carbon stock per ecological response unit in reference and current conditions

System Type	Ecological Response Unit	Reference Condition (tons)	Current Condition (tons)	Percent Departure from Reference Condition
Desert	Creosote Bursage Desert Scrub (CB)	74,381	74,987	0.8%
Desert	Sonoran Mid-Elevation Desert Scrub (SOS)	131,419	117,450	-10.6%
Desert	Sonoran Paloverde Mixed Cactus Desert Scrub (SP)	567,303	557,500	-1.7%
Grassland	Semi-Desert Grassland (SDG)	1,066,990	1,467,554	37.5%
Shrubland	Interior Chaparral (IC)	9,158,159	7,024,661	-23.3%
Woodland	Pinyon-Juniper Grass (PJG)	1,146,396	1,194,164	4.2%
Woodland	Juniper Grass (JUG)	6,060,455	3,860,907	-36.3%
Woodland	Pinyon-Juniper Evergreen Shrub (PJC)	4,104,119	4,392,248	7.0%
Woodland	Pinyon-Juniper Woodland (PJO)	1,227,474	977,095	-20.4%
Woodland	Madrean Encinal Woodland (MEW)	1,764,092	2,207,052	25.1%
Forest	Ponderosa Pine - Evergreen Oak (PPE)	3,591,190	8,094,601	125.4%
Forest	Ponderosa Pine Forest (PPF)	1,120,008	1,671,252	49.2%
Forest	Mixed Conifer – Frequent Fire (MCD)	3,049,200	3,216,312	5.5%
(Not applicable)	Totals	33,061,184	34,855,782	5.6%

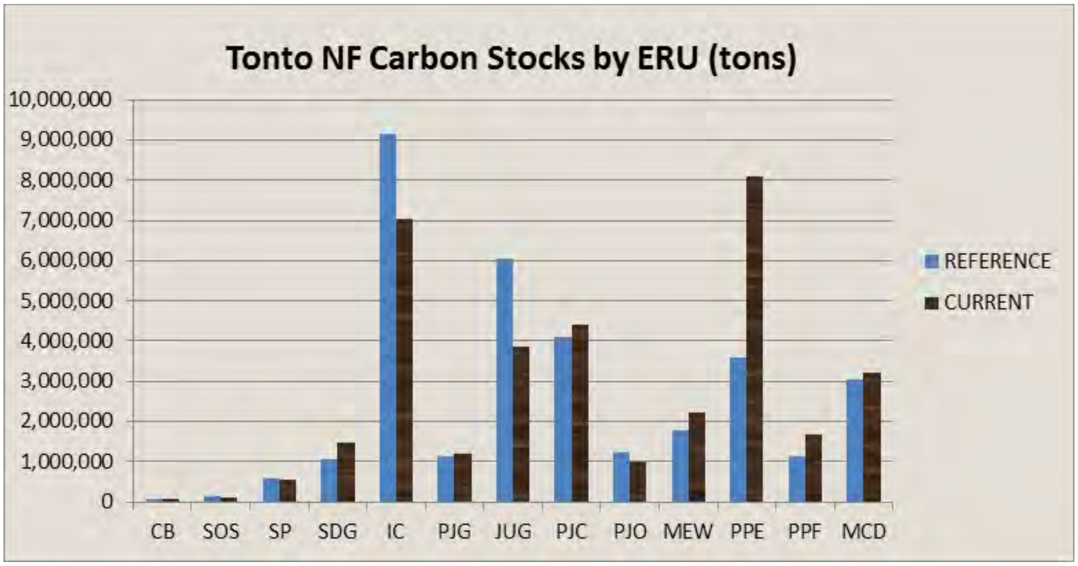


Figure 88. Biomass carbon stock by ecological response unit in current and reference conditions

(The previous table has the ecological response units corresponding to each code.)

Also of note is the considerable shift in biomass regimes of the Semi-Desert Grassland and Interior Chaparral ecological response units. In the Semi-Desert Grassland system, the amount of carbon has increased substantially, likely due to land use patterns of fire exclusion and herbivory which favor shrub development. The Interior Chaparral ecological response unit demonstrates the opposite – a reduction in biomass –due to a lack of mature, closed-canopy growth in favor of a more open grass and shrub state.

Trends: Biomass Projections

Many factors will influence future carbon stocks on the Tonto National Forest, and this assessment is not a comprehensive accounting of all possible outcomes. Factors such as climate change, fire frequency and severity, and management budgets are all outside the control of Tonto National Forest managers. As such, this assessment may be useful in conveying only general patterns and trends. However, general ecosystem dynamics in southwestern systems are fairly well understood and provide a good starting point for assessing trends in biomass carbon stocks. Vegetation conditions on the Tonto National Forest have been modeled into the future for most of its predominant ecological response units using state and transition modeling, including assumptions based on current management and disturbance patterns[11]. This allows the projection of relative biomass carbon contributions through time for key ecological response units (see a full description of process and methodology in Appendix 1). Using past observations of stand development dynamics and management applications for future projections is, admittedly, problematic in light of projected climate changes.

Figure 89 and table 141 depict 100-year projections for primary Tonto National Forest ecological response units against current and reference conditions.

[11] Modeling was conducted by Tonto National Forest and Region 3 staff, December 2014 – April 2015.

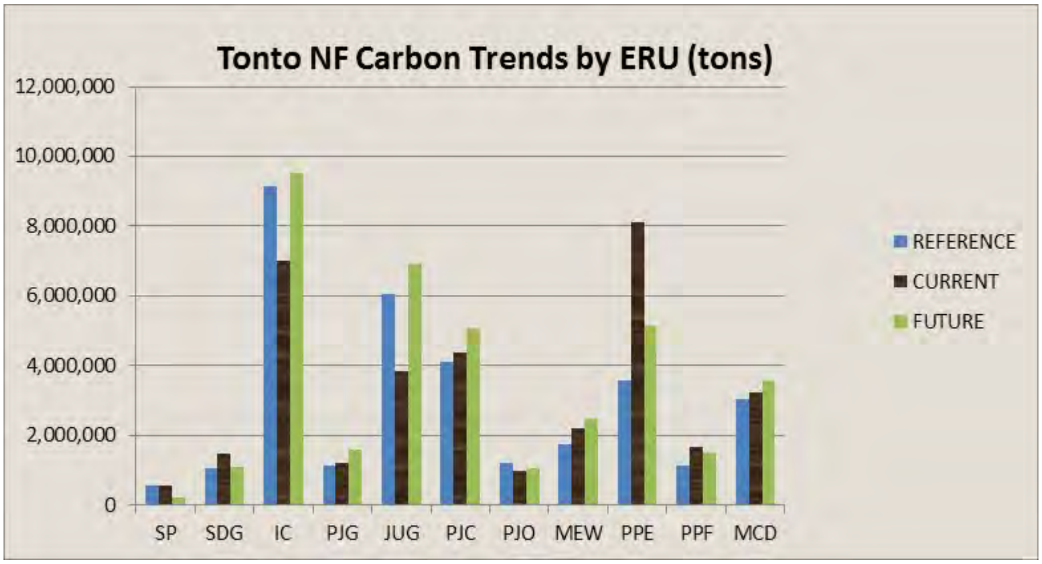


Figure 89. Trends in carbon stocks for Tonto National Forest ecological response units

Table 141. Projected carbon stocks for major ecological response units of the Tonto National Forest

Ecological Response Unit	Current Condition (tons)	Projected +100 years (tons)	Projected +100 years % Change from Current
Sonoran Paloverde Mixed Cactus Desert Scrub (SP)	557,500	226,290	-59.4%
Semi-Desert Grassland (SDG)	1,467,554	1,106,133	-24.6%
Interior Chaparral (IC)	7,024,661	9,526,837	35.6%
Pinyon-Juniper Grass (PJG)	1,194,164	1,587,904	33.0%
Juniper Grass (JUG)	3,860,907	6,929,106	79.5%
Pinyon-Juniper Evergreen Shrub (PJC)	4,392,248	5,074,243	15.5%
Pinyon-Juniper Woodland (PJO)	977,095	1,074,616	10.0%
Madrean Encinal Woodland (MEW)	2,207,052	2,486,501	12.7%
Ponderosa Pine - Evergreen Oak (PPE)	8,094,601	5,132,180	-36.6%
Ponderosa Pine Forest (PPF)	1,671,252	1,519,454	-9.1%
Mixed Conifer – Frequent Fire (MCD)	3,216,312	3,590,931	11.6%
Total	34,855,782	38,254,195	9.7%

These projections assume a continuation of current management and do not reflect changes in management that may emerge from the Tonto's ongoing effort to revise its land management plan. However, the results provide meaningful trend information about biomass carbon storage in the near future. The general pattern of biomass carbon stock projections on the Tonto National Forest (assuming continuation of current management patterns) indicates an increase in total carbon storage above current conditions in nearly all modeled ecological response units. Exceptions which display reductions in vegetation biomass carbon stocks are Sonoran Paloverde

Mixed Cactus Desert Scrub, Semi-Desert Grassland, Ponderosa Pine - Evergreen Oak, and Ponderosa Pine Forest ecological response units. Model improvements are necessary before too much interpretation is applied to predictions in the Semi-Desert Grassland and Ponderosa Pine Forest ecological response units. The reduction in biomass in Ponderosa Pine - Evergreen Oak is expected due to a heavy focus on restoration and fuel reduction management in this system on the Tonto National Forest (much of which occurs in the wildland-urban interface). In the Sonoran Paloverde Mixed Cactus Desert Scrub ecological response unit, the projected reduction in biomass stems results from the expansion of invasive annual grasses, which alters the fire regime and results in loss of native vegetation with greater biomass.

Carbon Emissions

Introduction

Carbon emissions have been characterized below using a case study synthesis from the Apache-Sitgreaves National Forests (Vegh et al. 2013), relevant to forested ecosystems of the Southwest in terms of natural processes and common management activities. The study provides a surrogate for emissions assessment in lieu of emissions data and analysis specific to the Tonto National Forest.

Background

To date, there has been no binding commitment by the Federal government or U.S. Forest Service for the regulation of carbon dioxide, though there has been increasing activity at State and regional levels to control carbon emissions to the atmosphere, prompting regulation, voluntary carbon exchanges, and carbon inventory and monitoring programs (Wiedinmyer and Neff 2007). The 2012 Planning Rule directs forests to assess baseline carbon stocks as part of the forest planning process (36 CFR 219.6(b)(4)), and though there are other carbon constituents released in wildfire and prescribed burning, carbon dioxide is the primary carbon compound and primary greenhouse gas associated with fire emissions (table 142).

Table 142. Proportion of greenhouse gases and carbon compounds

Compound/Particulate Matter	Proportion Greenhouse Gases	Proportion Carbon Constituents
Carbon dioxide	72.14%	90.82%
Water	21.18%	
Carbon monoxide	5.57%	7.02%
Atmospheric particulate matter less than 2.5 microns		0.60%
Nitric oxide	0.39%	
Methane	0.27%	0.34%
Volatile organic compounds	0.24%	0.31%
Organic carbon		0.31%
Non-methane hydrocarbon	0.20%	0.25%
Particulate matter greater than 10 microns		0.22%
Particulate matter less than 10 microns and greater than 2.5 microns		0.11%
Elemental carbon		0.03%

Source: NRC 2004

Though emissions by fire and other forest processes (for example, methane from the decomposition of wood) have a relatively minor impact on carbon stocks and flux, atmosphere-based emissions are strongly impacted by biosphere-atmosphere carbon fluxes at regional scales and represent the carbon component directly involved in the positive feedback of greenhouse gas forcing on climate change. In a given year in the Southwest, carbon emissions from fire can exceed fossil fuel emissions at regional scales (Wiedinmyer and Neff 2007). In their study of fire emissions, Wiedinmyer and Neff found that, on average, carbon emissions were 4 to 6 percent of the total anthropogenic emissions for the US. In a separate study, Woodbury et al. (2007) estimated that 10 percent of total anthropogenic emissions in the U.S. are captured by forest vegetation. This suggests forests can sequester more carbon than they emit and become an offsetting solution for anthropogenic emissions. The Intergovernmental Panel on Climate Change (IPCC) recognizes the potential for forest and woodland ecosystems to perform climate change mitigation (IPCC 2007).

In assessing carbon dynamics and emissions in the Southwest, Hurteau and others (for example, Hurteau et al. 2008; North et al. 2009; Hurteau and North 2010) went further and proposed that large releases of carbon to the atmosphere could be minimized by reducing stand densities. Prior to the Apache-Sitgreaves National Forests study (presented below), it had been hypothesized, and shown through dynamical modeling and observation (Kobziar et al. 2009; Martinson and Omi 2013; Pollet and Omi 2002), that reducing stand densities precludes large pulses of wildfire emissions with a reduction in uncharacteristic fire, such as stand-replacement fire in ponderosa pine forests. Preliminary research indicates the sustainable management of forests, along with careful consideration of byproducts and management residues, would balance forest carbon stocks and could also partially mitigate global climate change through increased carbon storage.

Apache-Sitgreaves Study Overview

Recent research on carbon dynamics and emissions related to various conventional forest management activities provides surrogate information to guide national forests of the Southwest in the assessment and management of carbon (Vegh et al. 2013). The study focused specifically on the Apache-Sitgreaves National Forests in eastern Arizona and western New Mexico and is being used here in lieu of more specific analysis of carbon emissions.

A key objective of the Apache-Sitgreaves study was to determine the long-term (100 years) difference in carbon stocks and carbon emissions between treated and untreated forest ecosystems. While the study was focused on the Ponderosa Pine Forest ecological response unit, the results can be abstracted to other forest and woodland ecosystem types for purposes of characterizing general trends among reference condition, no action, and treatment scenarios in terms of (1) fire carbon emissions, (2) total carbon stocks (aboveground and belowground, live and dead), and (3) live aboveground biomass. While the study by Vegh and others did not consider the effects of forest restoration per se (according to regional office desired conditions), it did evaluate the effects of reduced tree densities on carbon stocks and flux.

Analysis

In their study, Vegh and others (2013) compare the effects of different management alternatives on overall carbon stocks and emissions. They apply three management alternatives – no action, light thinning, and heavy thinning – to determine overall management effects on carbon sequestration and emissions flux. The researchers used the Forest Vegetation Simulator to model stand dynamics over a 100-year simulation and report outcomes for carbon stocks and emissions.

For annual treatment in the analysis simulation, all suitable stands on the Apache-Sitgreaves National Forests were prioritized in order of the following conditions:

1. Wildland-urban interface areas in high-departure plant communities.
2. Wildland-urban interface areas in moderate-departure plant communities.
3. Nonwildland-urban interface areas in high-departure plant communities.
4. Nonwildland urban interface areas in moderate-departure plant communities.
5. Wildland-urban interface areas in low-departure plant communities.
6. Nonwildland-urban interface areas in low-departure plant communities.

In all cases, departure is a measure of similarity between the current and reference (historic) vegetation structure. High departure reflects vegetation heavily altered from past structural conditions, and low departure indicates a distribution of structural states highly similar to those we would have expected pre-European settlement. In the Forest Vegetation Simulator simulations, individual stands were further prioritized for treatment according to basal area and quadratic mean diameter, so stands with the greatest stocking (that is, basal area) and the smallest trees (that is, quadratic mean diameter) would be given highest priority for treatment.

In their modeling, the investigators assumed conventional treatment scenarios and contemporary wildfire frequencies. Stands with a preponderance of large trees over 16 inches in diameter were not included due to some social constraints. Carbon emissions were estimated for wildfires, prescribed burning, and pile burning. In the simulations, all thinning harvests were followed by pile burning in the second year and broadcast burning in the tenth year. The researchers also assumed trees would regenerate successfully after burning.

Findings and Discussion

Vegh and others (2013) reported carbon emissions and stocks were affected by management alternatives and wildfire frequency. In the reporting, carbon stocks were divided into aboveground live biomass and into total carbon occurring aboveground and belowground, both live and dead. The following results were generated from the 100-year model simulation:

- The no action alternative resulted in the lowest total carbon emissions since no treatments would occur under these alternatives. The alternatives with management treatments produced approximately five times the total carbon emissions of the no action alternative.
- Carbon emissions by wildfire were lower in the treatment alternatives than in the no action, and wildfire emissions were lowest in the alternative with the greatest degree of thinning. Resulting wildfire emissions associated with the heavy thinning alternative were up to half the amount of emissions of the light thinning alternative and about one third less than the no action alternative.
- Total carbon stocks (aboveground and belowground, live and dead) were lower in the treatment alternatives than in the no action alternative, due to thinning and the removal of live tree biomass, assuming similar wildfire frequency and severity as the last three decades (1980 to 2009). The lowest carbon stocks were found in the heavy thinning alternative.
- Carbon stocks for live aboveground biomass alone were highest in the treatment alternatives, particularly in the second half of the simulation due to the accumulation of carbon in large, fire-resistant trees.

We might also conclude that at landscape scales, total aboveground carbon stocks would remain somewhat higher in the treatment scenarios than in the reference condition because of the number of untreated plant communities and a lower overall fire frequency compared to reference (due to fire suppression activities and loss of fine fuels in some ecological systems).

Soil Organic Carbon

Current Conditions

Soil organic carbon is the energy source for soil organisms which, through their activity and interactions with mineral matter, impart the structure to soil that affects its stability and its capacity to provide water, air, and nutrients to plant roots. The amount and kind of soil organic carbon reflects and controls soil development and, ultimately, ecosystem productivity (Van Cleve and Powers 1995).

Globally, soil organic carbon contains more than three times as much carbon as either the atmosphere or terrestrial vegetation (Schmidt et al. 2011). Forest soils are a critical part of any forest carbon accounting effort. Forest soils are the largest active terrestrial carbon pool and account for 34 percent of the global soil carbon pool (Bucholtz et al. 2013). Accurate quantification of regional soil carbon stocks is a necessary component of atmospheric carbon dioxide, soil productivity, and global climate change models. Soils represent a significant portion of the active carbon cycle, with estimates of organic carbon on the order of 1,500 to 2,000 petagrams of carbon or roughly two thirds of the terrestrial organic carbon stocks (Rasmussen 2006).

Attempts to characterize regional soil carbon stocks include both ecosystem- and soil-taxa-based approaches. The ecosystem approach involves averaging soil carbon data within a specific plant community or biome and multiplying the average soil carbon content by the estimated biome land area (Rasmussen 2006). This approach does not account for soil spatial heterogeneity and results in large variability of soil carbon estimations in an ecosystem or biome.

The soil taxa approach has been extensively described in the soil science literature (Rasmussen 2006) and includes segregating landscapes by soil taxa (instead of biomes) and using average taxa soil carbon and estimated land area to calculate soil carbon stocks.

The process used for the Tonto National Forest soil carbon stock assessment was an ecosystem-based approach through the aggregation of terrestrial ecological units (soil, vegetation, and climate) into ecological response units that represent the major potential natural vegetation communities.

The soil organic carbon values by ecological response unit in figure 90 represents soil pedon[12] data collected and analyzed during the Tonto National Forest terrestrial ecosystem survey (Robertson et al. 2014). Considerable soil organic carbon variation exists between ecological response units due to the variable numbers of soils sampled; the different kinds of soil taxa per ecological response units, and the scale for which map unit composition values represent both fine and coarse scales.

[12] A pedon is a three-dimensional sample of a soil just large enough to show the characteristics of all its horizons.

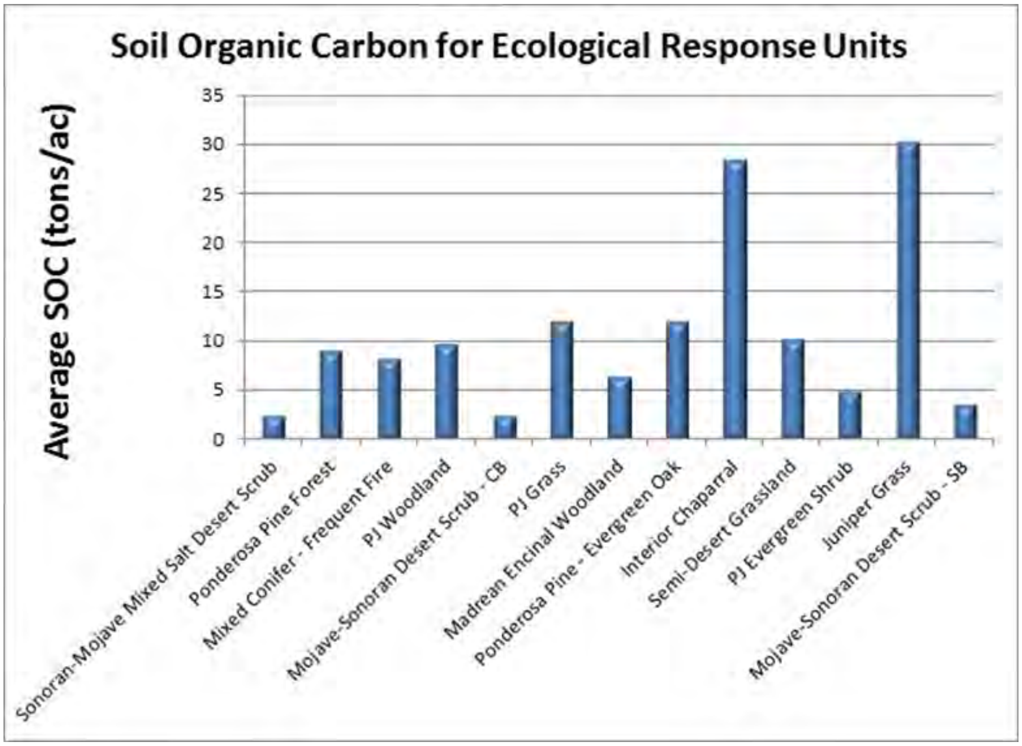


Figure 90. Average soil organic carbon (tons per acre) for ecological response units

Average soil organic carbon stock for ecological sites (pedons) sampled on the Tonto National Forest is generally greatest in the Juniper Grass ecological response unit of the woodland zone at 30.39 tons per acre and least the Sonoran-Mojave Mixed Salt Desert Scrub Mojave ecological response unit associated with the desert life zones at 2.5 tons per acre (figure 90). The ecological response units associated with the woodland life zones make the highest system contributing to the soil organic carbon stock when compared to the other ecological response units, accounting for 72 percent of total soil organic carbon by land area for the Tonto (table 143).

Table 143. Total soil organic carbon for ecological response units

Ecological Response Unit and Code	Soil Organic Carbon (tons)
Sonora-Mohave Mixed Salt Desert Scrub (SDS)	55,143
Ponderosa Pine Forest (PPF)	341,361
Mixed Conifer - Frequent Fire (MCD)	437,236
Pinyon-Juniper Woodland (PJO)	554,034
Sonora-Mojave Creosote-Bursage Desert Scrub (MSDS CB)	180,463
Pinyon-Juniper Grass (PJG)	984,968
Madrean Encinal Woodland (MEW)	612,312
Ponderosa Pine - Evergreen Oak (PPE)	2,651,088
Interior Chaparral (IC)	8,403,750
Semi-Desert Grassland (SDG)	3,588,417
Pinyon-Juniper Evergreen Shrub (PJC)	2,030,277
Juniper Grass (JUG)	12,655,764
Sonoran Paloverde-Mixed Cactus Desert Scrub (MSDS SP)	2,323,549

Rasmussen (2006) found the montane pine forest biomes of Arizona contain the greatest soil organic carbon stock; however, the pinion-juniper biome, which covers 20 percent of the land area in Arizona, contains the largest overall soil organic carbon stocks (27 percent). The montane pine forest biomes for the Tonto National Forest account for approximately 10 percent of the soil organic carbon stock based upon land area.

The desert and Semi -Desert Grassland ecological response units also contribute significantly to the overall soil organic carbon stock for the Tonto National Forest. They account for approximately 2,559,155 tons and 3,588,417 tons of soil organic carbon or 7 percent and 10 percent of the soil organic carbon stock by land area.

Trends

The current trend for sustaining soil organic carbon is strongly influenced by growth and yield of vegetation in the ecological response units and by activities that remove biomass from the soils surface, including climatic factors that provide temperature and moisture condition for weathering and decomposition of aboveground and belowground biomass. Given the projection that biomass carbon will increase into the future, it is logical to assume soil organic carbon will remain the same or potentially increase under current rates of decomposition. Current Region 3 soil quality technical guidance is to maintain surface coarse woody material in woodlands and forests to ensure microbial populations for nutrient cycling (Graham et al. 1994).

The exception to this would be grasslands and shrublands ecological response units where surface biomass has decreased due to consumptive harvesting by ungulates, erosion (wind and water) and other disturbances (for example, fire).

Summary and Conclusions

Biomass

Table 140 summarizes reference (historic) and current carbon conditions for ecological response units of the Tonto National Forest. On an acre-for-acre basis, the desert ecosystems (Sonora-Mojave Creosote-Bursage Desert Scrub, Sonoran Mid-Elevation Desert Scrub, and Sonoran Paloverde-Mixed Cactus Desert Scrub ecological response units) have the least biomass carbon concentration historically (about 1 ton per acre), while Mixed Conifer - Frequent Fire has the greatest (about 59 tons per acre). The remaining ecological response units ranged from 3 to 31 tons per acre, with forest ecological response units having the greatest concentrations, followed by Interior Chaparral, and then woodland and grassland ecological response units.

Two ecosystems, Interior Chaparral and Juniper Grass, currently demonstrate the largest reductions from reference conditions. In Interior Chaparral ecological response unit, biomass carbon stocks on the Tonto National Forest are 23.3 percent lower than under reference (equating to a 2.1 million ton reduction across the Tonto), likely due to a history of fire management that favored a mosaic burn pattern across the landscape over stand-replacing events. Our model predictions indicate an anticipated recovery of biomass carbon above that calculated to have occurred in reference conditions (see figure 88). The recovery results from a greater proportion (29 percent current versus 5 percent reference) of the ecological response unit in the mid-development shrub state at the expense of a mature, closed-canopy state (65 percent current versus 93 percent reference). In the Juniper Grass ecological response unit, the current biomass carbon stock is 36.3 percent below reference condition levels (totaling a 2.2 million ton reduction across the Tonto), likely due to historic chaining activity that removed large quantities of juniper from this ecosystem. Model predictions are for an increase in biomass carbon stocks in this ecosystem above reference levels resulting from tree recruitment into the currently overabundant grass/forbs/shrubs state (63 percent current versus five percent reference).

Some systems currently hold much larger biomass carbon stocks than they would have under reference conditions: Semi-Desert Grassland, Ponderosa Pine - Evergreen Oak, and Ponderosa Pine Forest ecological response units. The largest increase currently occurs in the Ponderosa Pine - Evergreen Oak ecological response unit, at 125 percent above reference levels and a total of 4.5 million tons above reference across the Tonto. After 100 years of restoration and fuel reduction activities, model predictions indicate a reduction in biomass carbon stock to 43 percent above reference conditions in Ponderosa Pine - Evergreen Oak ecological response unit (1.5 million tons above reference conditions across the Tonto National Forest). The biomass carbon stocks in Ponderosa Pine Forest and Semi-Desert Grassland ecological response units are currently 49 percent and 37.5 percent above reference condition, respectively. In both cases, our model results indicate a reduction in biomass carbon after 100 years (see figure 89 and table 141), but as noted earlier, these models are presently under improvement and results may vary after this work is completed.

In future trends for forest and woodland systems, carbon stocks are projected to increase on the Tonto (figure 89) except in Ponderosa Pine - Evergreen Oak and Ponderosa Pine Forest ecological response units. The most substantial increases are in the woodland systems (table 141), likely as a consequence of trends in low fire frequency and minimal forest management such as harvest thinning. While many factors work to drive these projected increases, two primary forces are noteworthy in this process: stand density and stand size (expressed in R3 modeling as stand cover class and stand size class, respectively).

The patterns of carbon stock loss and gain in some of the less biomass-rich ecological response units are nonetheless interesting and important. Projected biomass carbon stock loss in the Sonoran Paloverde-Mixed Cactus Desert Scrub ecological response unit is 9.8 thousand tons across the Tonto. While this is minor relative to the total mass of carbon stored in the Tonto's other vegetation systems, it is notable that we are predicting an almost 60 percent reduction in biomass carbon stock in this ecological response unit over the next 100 years. This forecast is driven largely by the projected expansion of invasive annual grasses in the Sonoran Paloverde-Mixed Cactus Desert Scrub ecological response unit.

Current management does not appear adequate to keep Tonto systems at biomass levels commensurate with reference conditions. Current conditions and management trends favor closed-canopy systems, which in turn store more carbon than their open-canopy counterparts. In ecological response units showing increases, state-and-transition modeling suggests current management intensities are not sufficient to overcome the current overrepresentation (in relation to reference conditions) of closed states, resulting in a continuation of excess carbon storage compared to reference conditions. Across the Tonto National Forest, while current biomass carbon stocks are 5.4 percent above reference, our 100-year projections indicate that, under current management, carbon stocks will rise to 15.7 percent above reference (a total excess of 5.2 million tons).

Carbon Emissions

Similar to implications of biomass conditions and resource management, the research synthesis on carbon emissions convey significant trade-offs among potential carbons strategies. Although the total carbon emissions were higher for the harvest alternatives in the study considered here

(Vegh et al. 2013), thinning and fuels reduction revealed lower wildfire emissions and reduced risk of uncharacteristic wildfire. The study also suggests systematic thinning and burning lead to greater live aboveground sequestration in the long term. It is also important to keep in mind the Apache-Sitgreaves National Forests are starting with uncharacteristically high biomass levels after a century of fire suppression, and strategies to maximize carbon sequestration and sustain carbon stores are not necessarily compatible (Hurteau and Wiedinmyer 2010). The indirect goal of contemporary management is to reduce, at least in part, current carbon stocks to pre-settlement levels.

In the future, the benefits to reduced emissions and increased carbon sequestration may be more pronounced. First, because live trees continually sequester carbon and are a more stable carbon sink than dead biomass generated by uncharacteristic fire, insect outbreaks, drought, and other stress, proactive management and broad-scale fuel reduction may be preferable for the long-term mitigation of atmospheric carbon. Second, there is the related issue of trees regenerating poorly or not at all following uncharacteristic fire in some forest types (Savage and Mast 2005). Other investigators (Dore et al. 2008) also show poor regeneration after stand-replacement fire in ponderosa pine can render plant communities as carbon sinks for many years after the fire. This casts further doubt on the sustainability of a strategy that maximizes sequestration while indirectly promoting uncharacteristic fire and reduced ecosystem productivity (Hurteau and Wiedinmyer 2010).

The Apache-Sitgreaves study does not represent a comprehensive analysis of the carbon emissions from forest management scenarios. A full accounting would include emissions from the harvest, transfer, and processing of any wood products; the sequestration and decomposition of those products and other forest residues; and the emissions from the associated energy consumption (Cameron et al. 2013). Using a 100-year model simulation, Cameron and others determined that, even with an industrial forestry theme, the ratio of storage to emissions was 0.58. They also showed if wood destined for paper and pulp was instead redirected to less lucrative biomass consumption, the storage ratio could increase substantially to 2.7.

Also for consideration are the effects, by increased carbon dioxide levels, on vegetation productivity and the potential for negative feedback by emissions on climate forcing. Such a feedback loop would involve carbon emitting processes, increased carbon dioxide levels, and fertilization of the atmosphere, followed by an increase in vegetation production and increased carbon capture and sequestration (mitigation). Some research indicates vegetation productivity increases with elevated carbon dioxide levels, but productivity rates soon level off as other factors appear to compete with the growth benefits (Archer 2011, Penuelas et al. 2011).

Finally, some have forwarded the notion of carbon carrying capacity as a potential foundation for carbon management plans (Keith et al. 2009, 2010, Hurteau et al. 2010). Carbon carrying capacity is the maximum amount of aboveground carbon that can be sustainably stored, according to climatic conditions and the disturbance regime of a system. Carbon carrying capacity may be a useful consideration for optimizing carbon stocks according to the inherent capabilities and processes of a given ecosystem.

Soil Organic Carbon

While most woodland and forest ecological response units will maintain biomass carbon in support of soil organic carbon for the future, the continued loss or displacement (patchiness) of grassland and shrubland surface biomass could result in slower and diminished contributions to soil organic carbon stocks and influence long-term soil productivity. Ecological response units where existing soil conditions are rated impaired or unsatisfactory due to the lack of surface litter are most susceptible to continued reductions of soil organic carbon over time. Soil conditions that are rated satisfactory will continue to maintain soil organic carbon values and a loss of long-term soil productivity is unlikely.

The effects of climate change on the decomposition rates and stability of soil organic carbon are presently being debated (Davidson and Janssens 2006).